HICKOK

MODELS 515, 517, 5015, 5015LD AND 5315

15 MHz SOLID STATE TRIGGERED

OSCILLOSCOPES

HICKOK ELECTRICAL INSTRUMENT COMPANY
10514 Dupont Avenue • Cleveland, Ohio 44108 • Phone 216-541-8060

MODELS 515, 517, 5015, 5015LD AND 5315

15 MHz SOLID STATE TRIGGERED

OSCILLOSCOPES

INSTRUCTION MANUAL

(Stock No. 2490-685A)

The Hickok Electrical Instrument Company

10514 DUPONT AVENUE • CLEVELAND, OHIO 44108 • (216) 541-8060 • TWX: 810-421-8286

WARRANTY

IMPORTANT

The following warranty shall be void if the registration card is not properly completed and returned to the Hickok factory, post marked within ten days after date of purchase.

The Hickok Electrical Instrument Co. warrants this instrument of its manufacture to be free from defects in material and workmanship for a period of two years (24 months) from the date of original purchase, subject to the following conditions.

a. Any instrument found to be defective during the first twelve month period after date of purchase may be returned, transportation prepaid, to the factory for repair or, at our option, replacement without charge.

b. Any instrument found to be defective during the second twelve month period after date or purchase may be returned, transportation prepaid, to the factory for repair subject to a minimal handling charge for each time the instrument is returned. Contact the Hickok factory for information regarding this service charge.

This warranty does not apply to any of our products which have been repaired or altered by unauthorized persons, or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced or removed. Neither shall the warranty apply where a warranty registration card has not been properly completed and returned to us promptly after purchase. This warranty is in lieu of all other warranties whether expressed or implied.

RETURNING EQUIPMENT FOR REPAIR

Before returning any equipment for service, the factory must first be contacted, giving the nature of the trouble. Instructions will then be given for either correcting the trouble or returning the equipment. Upon authorization, this equipment should be forwarded directly either to:

Hickok Electrical Instrument Co.
10514 Dupont Avenue
Cleveland, Ohio 44108

or

Hickok Electrical Instrument Co.
1714 Carrollton Avenue
Greenwood, Mississippi 38930

or to a designated service station in your locality.

SECTION		Page
I	GENERAL INFORMATION	1-1
	1-1 Description	1-1
	1-2 Specifications	1-2
	1-3 Controls and Their Uses	1-4
II	OPERATION	2-1
	2-1 Preliminary	2-1
	2-2 General	2-1
	a. Voltage vs Voltage Graphing	2-1
	b. Voltage vs Time Graphing	2-1
	2-3 Initial Set-Up	2-2
	2-4 Cathode Ray Tube (Crt) Alignment	2-2
	2-5 Vertical Dc Balance Adjust (Channel A)	2-2
	2-6 Probe Calibration Voltage	2-2
	2-7 Use of Probes	2-2
	2-8 Operation of Vertical Controls	2-2
	2-9 Dual and Add Operation	2-3
	2-10 Operation of Triggering Controls	2-3
	2-11 Operation of Horizontal Controls	2-4
III	APPLICATIONS	3-1
	3-1 Typical Voltage Measurements	3-1
	a. Ac Component Measurements	3-1
	b. Dc Level Measurements	3-1
	3-2 Typical Time Measurements	3-2
	a. Measurement of Pulse Duration	3-2
	b. Measuring the Period of Periodic Waveforms	3-2
	3-3 Video Signal Measurements	3-2
	3-4 Observing Modulated RF Signals Over 15MHz	3-3
IV	THEORY OF OPERATION	4-1
	4-1 Power Supply with Blanking Circuit	4-1
	a. General Description	4-1
	b. Line-Operated Pre-Regulator	4-1
	c. Inverter Drive Circuitry	4-1
	4-2 Vertical Preamps	4-2
	4-3 Vertical Switching	4-2
	4-4 Vertical Final	4-2
	4-5 Trigger Pickoff	4-3
	4-6 Blanking Circuit	4-3
	4-7 Trigger Amplifier	4-3
	4-8 Auto Gate	4-4
	4-9 Trigger Gate	4-4
	4-10 Sweep Circuit	4-4
	4-11 Television Sync Separator	4-4
	4-12 External Horizontal System	4-6
V	CALIBRATION PROCEDURE	5-1
	5-1 Calibration Equipment Required	5-1
	5-2 Power Supply Calibration	5-1
	5-3 Horizontal Preamplifier Calibration	5-1
	5-4 Vertical Final Current Adjustment	5-1
	5-5 Horizontal Final Current Adjustment	5-2
	5-6 Sweep Timing Calibration	5-2
	5-7 Vertical Amplifier Gain Adjustment	5-2
	5-8 Attenuator Compensation	5-2
	5-9 Crt Capacity Balance and Intensity Limit Adjustments	5-3

SECTION			Page
VI	SERVICING		6-1
	6-1	General	6-1
	6-2	Precautions to be Observed when Servicing the Oscilloscope	6-1
	6-3	Servicing and Troubleshooting Procedures	6-1
		Troubleshooting Chart	6-2
VII	PARTS LIST		7-1

FIGURE		Page
1-1	Single Trace and Dual Trace Oscilloscope Models	1-1
1-2	Models 517 and 5315 Controls and Their Locations	1-7
1-3	Models 515, 5015 and 5015LD Controls and Their Locations	1-7
2-1	Voltage vs Voltage Diagram	2-1
2-2	Voltage vs Time Diagram	2-1
2-3	Calibrator Output Voltage Display	2-3
2-4	Positive and Negative Trigger Slopes	2-4
2-5	Action of Sync Stripper Circuit	2-4
3-1	Measurement of AC Component Amplitude	3-1
3-2	Measurement of Period Duration	3-2
3-3	Direction of Applied Sync Pulses	3-2
4-1	Blanking Control Pulse Waveform	4-3
4-2	Trigger Amplifier Waveforms	4-4
4-3	Simplified Diagram of Hold Off, Trigger Gate and Sweep Circuitry	4-5
6-1	Servicing Etched Circuit Board	6-3
7-1	Power Supply and Blanking PC Board	
7-2	Vertical Amplifier PC Board (Dual Trace Only)	
7-3	Vertical Amplifier PC Board (Single Trace Only)	
7-4	Horizontal and Sweep PC Board	
7-5	Vertical Final Amplifier PC Board	
7-6	Power Supply and Blanking Schematic	
7-7	Vertical Amplifier Schematic (Dual Trace Only)	
7-8	Vertical Amplifier Schematic (Single Trace Only)	
7-9	Horizontal and Sweep Schematic	
7-10	Vertical Amplifier Schematic (Model 5015)	

SECTION I
GENERAL INFORMATION

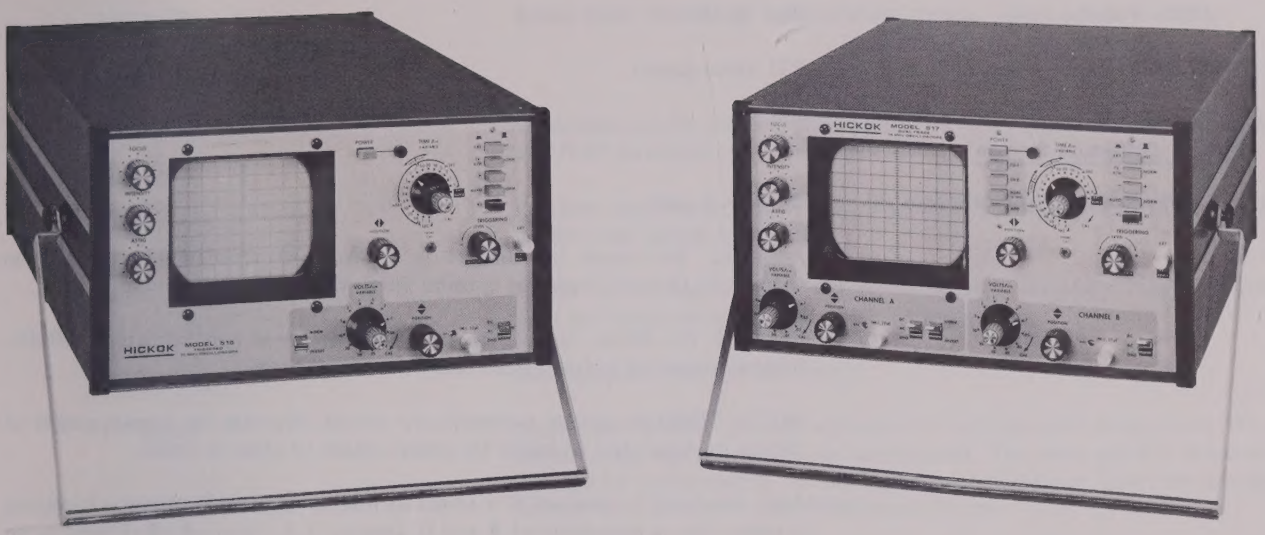


Figure 1-1. Single Trace and Dual Trace Oscilloscope Models

1-1 DESCRIPTION

The Hickok Oscilloscopes covered by this instruction manual have been especially designed to fulfill the need for a highly stable, triggered sweep, solid state oscilloscope for general purpose industrial use. Due to many unique features, it is also ideally suited for use by television, audio and radio service technicians. This manual covers both the Models 515, 5015, and 5015LD single trace versions, and the Models 517 and 5315 dual trace versions.

Special features of this instrument which are essential for testing and servicing modern electronic equipment are:

a. On the dual trace versions, the **VERTICAL SYSTEM** has dual channel amplifiers which allow two waveforms to be displayed simultaneously to compare their time or phase relationship. The two channels can be displayed separately, simultaneously or added together algebraically.

b. For all models, the **VERTICAL CHANNELS** include a step attenuator, to provide calibrated input voltage ranges, and a variable gain control to permit adjustment between steps or ranges. Vertical input may be either ac or dc coupled. Special circuitry provides minimal overshoot, ringing and drift in the amplifier.

c. The **HORIZONTAL AMPLIFIER** system provides for dc coupled inputs and includes a variable gain control. The **X1/X5** gain switch permits expanding the display for easy viewing.

d. A digital type **TRIGGER** circuit offers very stable triggering with minimum jitter to 30MHz without the use of high frequency sync adjustments. This permits the oscilloscope to be used to full bandwidth.

e. Calibrated **SWEEP** speeds in 18 steps with continuous adjustment between steps.

f. Special circuitry and control settings for viewing **TV HORIZONTAL** lines and **VERTICAL** frames. Switching from **TV V** to **TV H** is accomplished automatically by the **TIME/cm** switch.

g. **OVERLOAD** protection on all ranges to protect the equipment from accidental application of excessive input voltage.

h. **Z AXIS BLANKING** is provided by a Z axis input connector located on the back panel of the oscilloscope.

1-2 SPECIFICATIONS

Cathode Ray Tube

Type:	5DEP31F
Accelerating Potential:	1.9kV
Usable Viewing Area:	8cm X 10cm
Phosphor:	P31 (blue-green)

Vertical Deflection System

Display Modes (Dual Trace only):	Channel A only Alternate: the signal on channel B is displayed alternately with that on channel A. Internal triggering is taken from channel A at all times. Chopped: the display is switched between channels at approximately 100kHz. Internal triggering is taken from channel A at all times. NOTE: **TIME/cm** switch automatically selects alternate for sweep speeds of .5msec to .5μsec and chopped for sweep speeds of .2sec to 1msec. Add: the signal on channel B is added to that on channel A. Internal triggering is taken from a composite of A and B. Display is A + B or -A +B depending on channel A **NORM/INVERT** switch. Channel B only: internal triggering is taken from channel B.
Deflection Sensitivity:	10mV/cm to 50V/cm in 12 calibrated steps, accuracy ±3%. A variable control (uncalibrated) provides continuous adjustment between steps and extends the range to 5mV/cm.
Input:	Ac or dc coupled or grounded amplifier input selected by switch.
Input Impedance:	1 megohm ±1%, shunted by approximately 32pF.
Bandwidth:	Ac coupled: 5Hz to 15MHz. Dc coupled: dc to 15MHz. Frequencies up to 27MHz can be viewed with a maximum display of approximately 2cm at 27MHz.
Rise Time:	23 nanoseconds.
Overshoot:	5% or less.
Max Input Voltage:	600 volts dc plus ac peak.
Delay Line (Model 5015 only):	Provides sufficient base line prior to start of displayed waveform to permit viewing of the fast rise of the leading edge.

Horizontal Amplifier

Deflection Sensitivity:	Continuously variable from .1 volts/cm to 5 volts/cm (to 50 volts/cm X5 multiplier).
Input:	Dc coupled.
Input Impedance:	1 megohm (nominal) shunted by approximately 40pF.
Bandwidth (with Horizontal Level Control full CW):	Dc to 1MHz.

Time Base Generator

Sweep Rates:	0.5μsec/cm to 0.2sec/cm in 18 calibrated steps. Accuracy ±5%. A variable control (uncalibrated) permits continuous adjustment between steps and extends the range to 1sec/cm. In X5 multiplier position, all sweep speeds are 1/5 switch setting. Max sweep rate is 100ns/cm.
Linearity:	Better than 1% through full horizontal sweep.

Triggering System

Source:	All models can be triggered from an internal or external source as selected by the **INT/EXT** pushbutton.
Auto:	Provides continuous triggering in the absence of a trigger signal when selected by the auto pushbutton.
Slope:	Either the positive or negative slope of the input waveform may be selected to start the sweep as selected by the +/- pushbutton.
Level:	Adjustable by front panel control.
TV Sync:	Sync filter circuits provide horizontal or vertical sync pulses from the composite video signal to sync the oscilloscope. The sync signal is automatically selected by sweep switch, for horizontal sync 50μsec to .5μsec position and for vertical sync .2sec to .1msec **TIME/cm** positions.
Sensitivity, Internal:	0.5 division of deflection up to 4MHz and 0.5 to 1.5 divisions from 4MHz to 15MHz.
External:	200mV to 5V peak to peak squarewave. 400mV to 5V peak to peak sinewave.
Input Impedance (External Trigger):	1 megohm (nominal) shunted by approximately 32pF.

Z Axis Blanking

Input Signal:	T^2L input "0" blanks trace (0 volts at 1.6ma). T^2L input "1" unblanks (+2.8 volts or open circuit).
Max Input Repetition Rate:	100kHz.

Miscellaneous

Probe Calibration Voltage:	Approximately 7.5V peak to peak, 1kHz squarewave.
Power Requirements:	105 to 125V, 50 to 60Hz, 50 watts, for standard model. 205 to 260V, 50 to 60Hz model available from factory when specified by customer (Model 515E, 517E).
Overall Dimensions and Weight	14-5/8"W x 7"H x 17-1/2"D (37.1cm x 17.8cm x 44.4cm). Dual Trace: 13.5 lb (6.14kg). Single Trace: 12.0 lb (5.45kg).

Accessories

The Single Trace is supplied with a Model SP-6 Probe which is a combination 10:1 Low Cap and 1:1 Direct Probe.

The Dual Trace includes one SP-6 Probe and one SP-7 Probe which is a 10:1 Low Cap Probe only.

All the models include a mylar screen overlay for vector scope operation.

1-3 CONTROLS AND THEIR USES

Refer to Figure 1-2 for the Models 517 and 5315 and Figure 1-3 for the Models 515, 5015, and 5015LD. Note that the controls are grouped into color shaded functional areas. The blue areas are for vertical modes and the green area is for triggering.

	Item Number	
POWER switch and lamp	1	Push-on-push-off switch applies power to unit. Lamp indicates power to unit. Lamp indicates power on when lit. Allow 1 minute for CRT warm-up.
FOCUS control	2	Adjusts focus of CR tube beam to control sharpness of trace.
INTENSITY control	3	Adjusts brightness of trace.
ASTIG control	4	Use in conjunction with **FOCUS** control to provide maximum sharpness of trace.
CHANNEL A VOLTS/cm switch	5	Vertical attenuator. Provides coarse adjustment of A vertical sensitivity in 12 calibrated steps from 0.01 to 50 volts per cm when **VARIABLE** vertical gain control (6) is in the **CAL** position.
CHANNEL A VARIABLE gain control for vertical attenuator	6	Permits fine adjustment of vertical sensitivity (uncalibrated) between the steps of the **VOLTS/cm** switch (5), from .005 to 50 volts/cm. With this control set in the extreme clockwise **(CAL)** position the vertical attenuator steps are calibrated.
CHANNEL A vertical **POSITION** control	7	Permits vertical positioning of the A channel trace.
CHANNEL A vertical **BAL** adjustment	8	Adjusts the offset of the vertical amplifier so that the trace does not move when the **VOLTS/cm** switch (5) is changed from one position to another.
CHANNEL A vertical input jack	9	Coaxial input terminal for vertical amplifier 1 MΩ ±1% impedance.
CHANNEL A DC/AC/GND vertical input switch	10	Selects dc coupled, ac coupled, or grounded amplifier inputs for vertical input connector (9).
Trace **INVERT** switch	11	Permits the inversion of positive or negative vertical input signals so that they can be displayed in the same orientation on the screen. For proper triggering of video signals this control should be set so the sync tips point down. Note that this control also inverts the direction in which the position control moves the trace. In **ADD** mode (Model 517) this also permits a display of the difference (B-A) signal between channel A and channel B. (The unmarked center position is non-inverting).
CHANNEL B VOLTS/cm switch	12 (Dual Trace only)	Vertical attenuator. Provides coarse adjustment of vertical sensitivity in 12 calibrated steps from 0.01 to 50 volts per cm when **VARIABLE** vertical gain control (13) is in the **CAL** position.
CHANNEL B VARIABLE control for vertical attenuator	13 (Dual Trace only)	Permits fine adjustment of vertical sensitivity (uncalibrated) between the steps of the **VOLTS/cm** switch (12). With this control set in the extreme clockwise **(CAL)** position the vertical attenuator steps are calibrated.

	Item Number	
CHANNEL B POSITION control	14 (Dual Trace only)	Permits vertical positioning of the B channel trace.
CHANNEL B vertical **BAL** adjustment	15 (Dual Trace only)	Adjusts the offset of the B vertical amplifier so that the trace does not move when the **VOLTS/cm** switch (12) is changed from one position to another.
CHANNEL B vertical input jack	16 (Dual Trace only)	Coaxial input terminal for B vertical amplifier. 1 MΩ ±1% impedance.
CHANNEL B DC/AC/GND vertical input switch	17 (Dual Trace only)	Selects dc coupled, ac coupled or grounded amplifier inputs for vertical input connector (16).
Horizontal **POSITION** control	18	Permits horizontal positioning of trace on CR tube screen.
PROBE CAL jack	19	Provides a square wave voltage of approximately 7.5 volts peak to peak at 1kHz for frequency compensating low capacitance divider probes when used with the oscilloscope.
TRIGGERING LEVEL control (also serves as **EXT HORIZ GAIN** control)	20	Adjustment determines starting point of sweep on waveform slope. Also adjusts magnitude of external horizontal input signals when the **TIME/cm** switch (27) is in the **EXT HORIZ** position.
EXT TRIGGERING/EXT HORIZ input jack	21	Coaxial input terminal for application of external trigger signals. Also serves as input for external signals to the horizontal amplifier when the **TIME/cm** switch (27) is in the **EXT HORIZ** position.
HORIZ GAIN X5/X1 switch	22	Permits increasing the horizontal gain by a factor of 5 to expand the display for easier viewing.
AUTO triggering switch	23	Automatically provides a base line when the sweep is not triggered.
+/– slope triggering switch	24	Selects either the positive or negative slope of the input waveform for start of trace.
TV V/H triggering switch	25	Switches in special filter circuits for displaying the composite video waveform at either vertical or horizontal rates, depending on the setting of the **TIME/cm** switch (27).
INT/EXT triggering switch	26	Selects the signal applied at the **EXT** input (21) as the trigger signal when depressed, otherwise internal trigger signal is used.
TIME/cm switch	27	Coarse horizontal sweep selector. Selects sweep time of 0.5μsec/cm to 0.2 sec/cm in 18 calibrated steps when **TIME/cm VARIABLE** control (28) is set to the **CAL** position. Also selects proper filter for TV sync triggering when **TV V/H** triggering switch (25) is depressed. **TV H** (horizontal) sync for sweeps of 50μsec/cm and faster, **TV V** (vertical) sync for sweeps 0.1msec/cm and slower. Also selects **ALT** or **CHOP** modes (Dual Trace only) of operation when **DUAL** switch (31) is depressed. **ALT** for sweeps of 0.5msec/cm and faster. **CHOP** for sweeps at 1msec/cm and slower.

	Item Number	
TIME/cm VARIABLE control	28	Permits fine sweep time adjustment (uncalibrated) between the steps of **TIME/cm** switch (27). When this control is set in its extreme clockwise position **(CAL)** the sweep time is calibrated.
CH A switch	29 (Dual Trace only)	Selects voltages connected to the A input only to be displayed on screen. Trigger voltage is taken from the A channel input voltage.
CH B switch	30 (Dual Trace only)	Selects voltages connected to the B input only to be displayed on the screen. Trigger voltage is taken from B input voltage.
DUAL switch	31 (Dual Trace only)	Selects voltages connected to both the A input and B input to be displayed as separate traces either chopped **(CHOP)** or alternately **(ALT)** depending on the setting of the **TIME/cm** switch (27) as follows: (a) **ALT** mode. Voltages which are connected to A and B inputs will appear alternately on screen during successive sweeps. Trigger voltage is taken from the A channel input voltage. (b) **CHOP** mode. Voltages which are connected to A and B inputs will appear simultaneously on screen by internally switching the crt beam at a 100kHz rate between the A and B channels. Trigger voltage is taken from A channel input voltage.
ADD switch	32 (Dual Trace only)	Selects voltages at the A and B inputs to be added together or subtracted from each other when used in conjunction with the A trace invert switch. Trigger voltage is taken from a composite of the A and B input voltage.

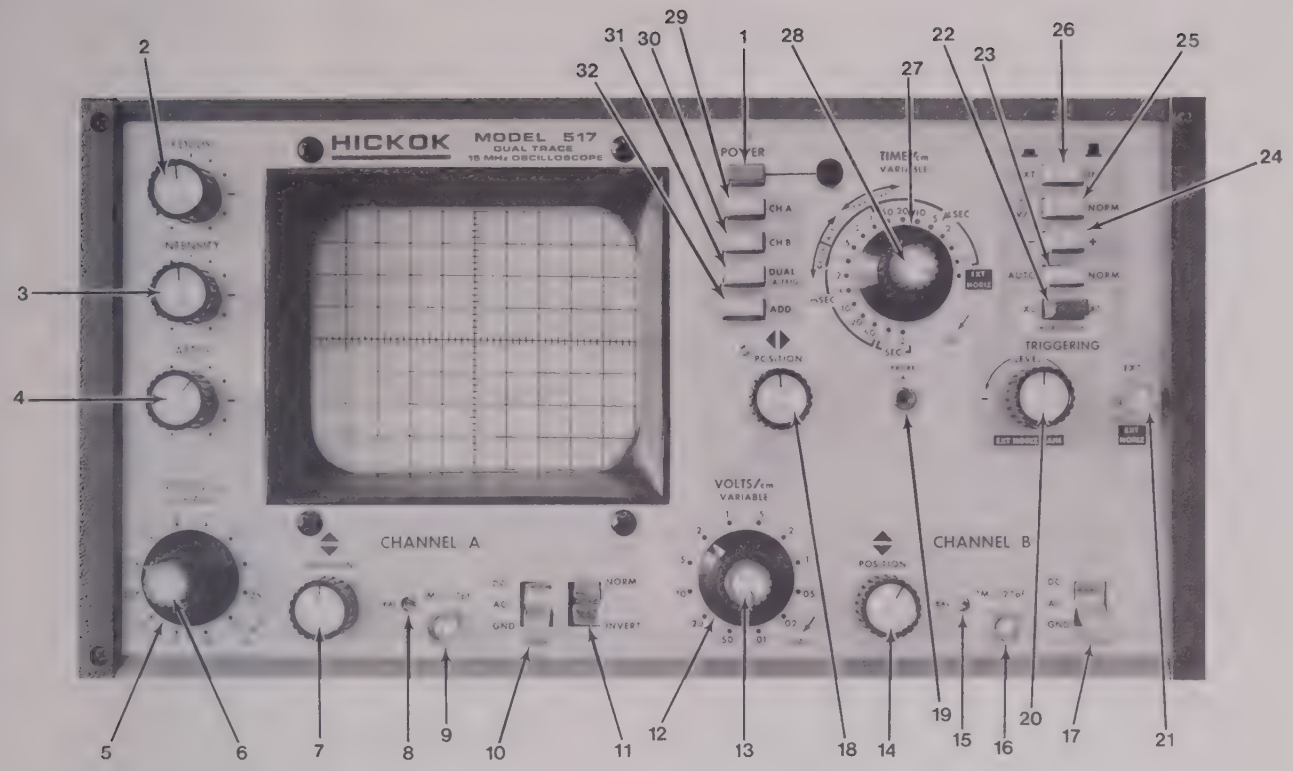


Figure 1-2. Models 517 and 5315 Controls and Their Locations

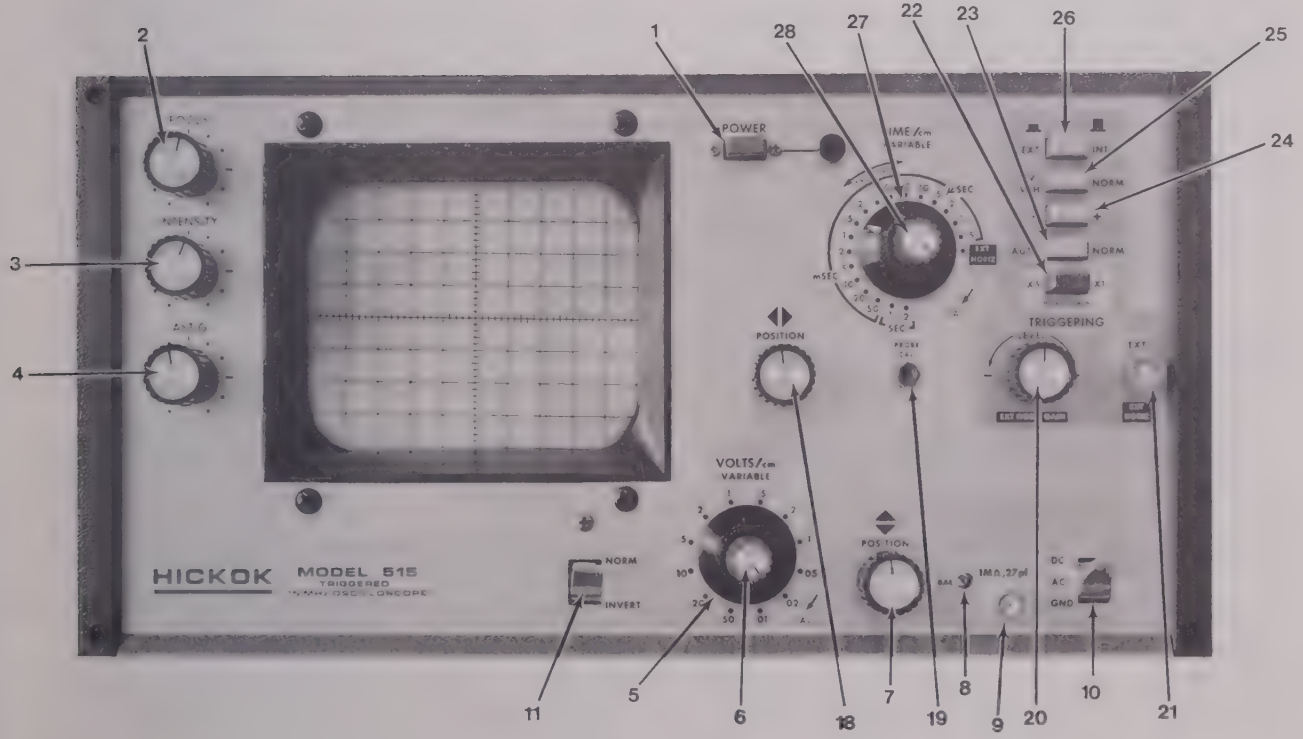


Figure 1-3. Models 515, 5015, and 5015LD Controls and Their Locations

SECTION II
OPERATION

2-1 PRELIMINARY

Upon receipt the oscilloscope should be visually inspected for physical damage. The shipping carton should be saved since it is designed to prevent damage to the cathode ray tube during shipment. DO NOT ATTEMPT TO RESHIP WITHOUT A PROPER CARTON.

DO NOT ATTEMPT TO OPERATE THIS OSCILLOSCOPE UNTIL THE SECTION OF THIS MANUAL ON OPERATION HAS BEEN READ AND IT IS CERTAIN THAT THE LINE VOLTAGE IS WITHIN SPECIFIED LIMITS.

REFER TO SPECIFICATION FOR INPUT LIMITS.

IF A THIRD WIRE GROUNDED POWER SOURCE OUTLET IS NOT AVAILABLE, AN APPROVED ADAPTER WITH GROUNDING LEAD SHOULD BE USED AND THE LEAD CONNECTED TO A SUITABLE GROUND TO PREVENT A POSSIBLE SHOCK HAZARD TO THE OPERATOR.

2-2 GENERAL

The oscilloscope is an instrument for the instantaneous graphing of voltages. The vertical axis of the graph is controlled by the vertical controls. These controls have green panel nomenclature. The horizontal axis of the graphs is controlled by the horizontal controls which have blue nomenclature. This oscilloscope displays two different types of graphs.

a. Voltage vs Voltage Graphing

With the voltage vs voltage graphing, input signals are applied to the vertical input and **EXT HORIZ INPUT**, amplified by the vertical and horizontal amplifiers, and applied to the vertical and horizontal deflection plates in the cathode ray tube. This mode of operation is useful for graphing the relationship between two voltages. Common applications are lissajous patterns for frequency comparison and vector scope measurements in television servicing. See Figure 2-1.

b. Voltage vs Time Graphing

With voltage vs time graphing, the input signal is applied to the vertical input, amplified by the vertical amplifier, and applied to the vertical deflection plates. The horizontal amplifier is connected to a triggered time-to-voltage generator which is internally contained in the oscilloscope. The function of this generator is to develop an output voltage whose magnitude is linearly related to the elapsed time after the generator was triggered. This produces a display which is voltage vs time. See Figure 2-2.

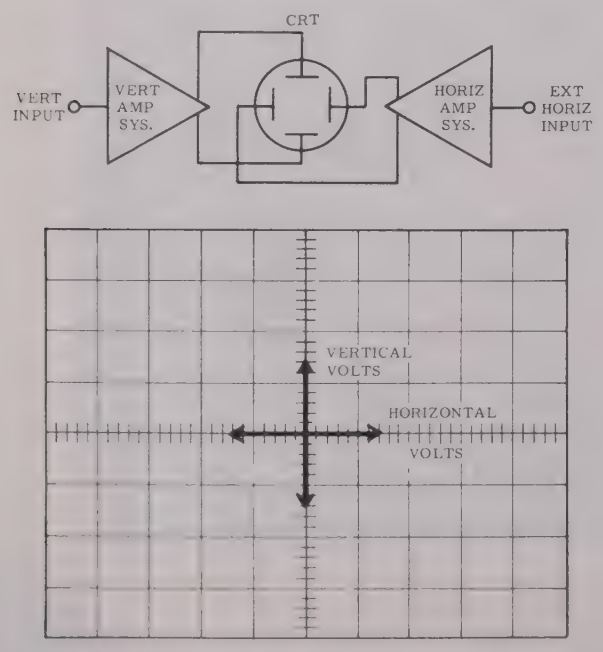


Figure 2-1. Voltage vs Voltage Diagram

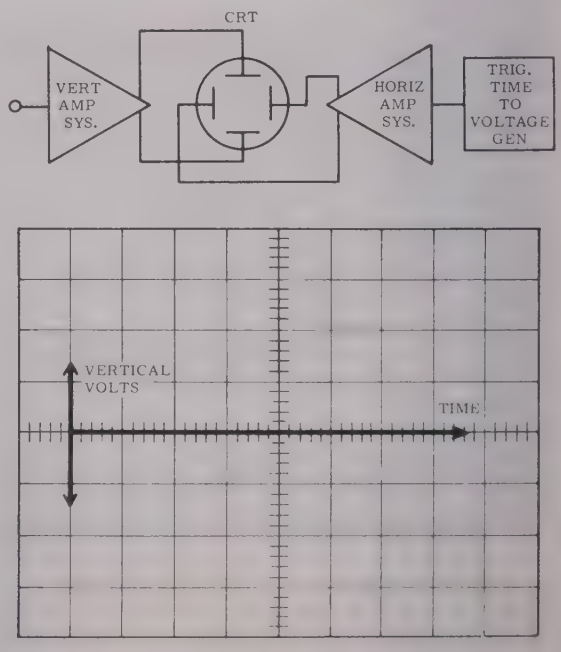


Figure 2-2. Voltage vs Time Diagram

2-3 INITIAL SET-UP

To check the oscilloscope for proper operation, plug the power cord into the power line using a third wire ground connection.

Set the front panel controls as follows:

POWER	Off
POSITION (Channel A)	Centered
INTENSITY	Maximum (CW)
POSITION (Horizontal)	Centered
HORIZ GAIN	**X1**
MODE (if dual trace 517)	**A**
VOLTS/cm switch (Channel A and B)	1V
VOLTS/cm VARIABLE (Channel A and B)	**CAL** (Clockwise)
Vertical input switch (Channel A and B)	**AC**
INVERT switch (Channel A and B)	**NORM**
EXT/INT	**INT**
TV/NORM	**NORM**
-/+	**+**
AUTO/NORM	**AUTO**
LEVEL	Centered
TIME/cm	**2mSEC**
TIME/cm VARIABLE	**CAL** (Clockwise)

With the controls set as above, move **POWER** switch to **ON** and allow three minutes for warm-up. A bright horizontal line should be observed. Using the horizontal **POSITION** control, position the trace so that the beginning of the sweep occurs at the first line at the left of the graticule. Reduce **INTENSITY** control setting and adjust **FOCUS** and **ASTIG** for a sharp display.

2-4 CATHODE RAY TUBE (CRT) ALIGNMENT

If the trace tilt is unacceptable, loosen the three screws on the perimeter of crt cap on back panel. Rotate cap until trace is properly aligned and tighten screws.

2-5 VERTICAL DC BALANCE ADJUST (CHANNEL A)

Set controls as per initial set-up.

a. With a screwdriver carefully adjust **BAL** until the trace is on the center graticule line.

b. Move **VOLTS/cm** control to the 5V range. If the trace has moved from the center graticule line, recenter it with the **POSITION** control.

c. Move **VOLTS/cm** control back to the 1V range. If the trace has moved, adjust **BAL** until the trace is again on the center graticule line.

d. Continue to adjust the **POSITION** when the **VOLTS/cm** switch is on the 5V range and adjust the **BAL** control when the **VOLTS/cm** switch is on the 1V range until trace shift is acceptable.

With careful adjustment of the **BAL** control, the trace will remain centered as the **VOLTS/cm** control is rotated; however, proper operation of the instrument is maintained as long as the trace moves less than 1cm when switching between the 1V/cm and 5V/cm positions. (Repeat above procedure for Channel B for Model 517.)

2-6 PROBE CALIBRATION VOLTAGE

With controls set as per the initial set-up, connect the **PROBE CAL** output to the vertical input connector. Center the display using the vertical position and horizontal position controls. This display should be as in Figure 2-3.

To obtain familiarity with the instrument, the controls may be manipulated as desired and the effects observed. Note that no combination of control positions can cause any damage to the instrument.

2-7 USE OF PROBES

Attenuator probes are frequently used to reduce resistive and capacitive loading of the circuit under test. The Hickok Model SP-6 or any standard probe which is capable of adjusting to a 35pF oscilloscope input capacity can be used. When making measurements with a probe, multiply the observed amplitude by the probe attenuation factor. The Hickok probe has a factor of 10:1 or 1:1.

To ensure the accuracy of high frequency and pulse measurements, probe adjustment is necessary with any 10:1 probe. To make this adjustment, proceed as follows:

a. Set the **VOLTS/cm** switch to **.1V,** and the input switch to **DC**, and connect the probe to the **PROBE CAL** output connector.

b. Set the **TIME/cm** switch to **.5mSEC** and adjust the trigger controls for a stable display.

c. Adjust the probe for sharp rise and best flatness of the positive peak.

2-8 OPERATION OF VERTICAL CONTROLS

The controls in the blue shaded areas of the panel control the deflection of the spot in the vertical direction.

a. The **VOLTS/cm** control and its concentric **VARIABLE** control allow continuous adjustment of the input sensitivity of the instrument from .005 to 50 volts/cm. With the **VARIABLE** control in its most clockwise position, the instrument is calibrated, with 12 voltages ranging in a 1, 2, 5 sequence. Regardless of the position of the controls the input impedance of the vertical input connector remains constant.

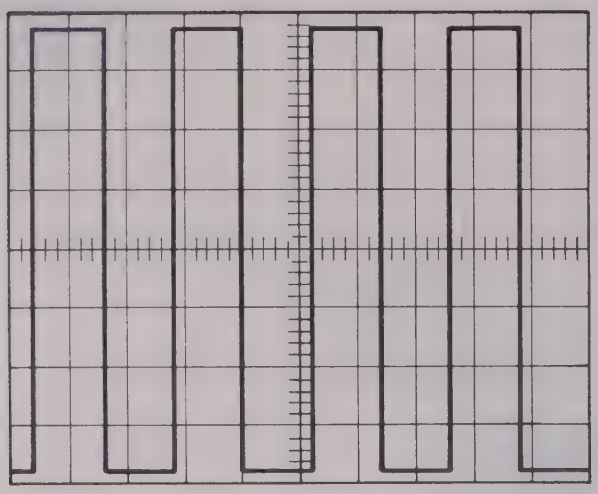


Figure 2-3. Calibrator Output Voltage Display

b. The vertical **AC/DC/GND** switch selects the type of coupling into the vertical amplifiers. In the **DC** position, the amplifier is direct coupled from the input connector through the vertical amplifier to the deflection plates in the crt. In the **AC** coupled position, this vertical amplifier has a capacitor inserted in series with its input which blocks any dc voltages and allows ac voltages to pass. This position is very useful for viewing ac voltages which ride on dc levels such as power supply ripple. In the **GND** position, the vertical input is disconnected from the amplifier input for easy determination of the zero voltage input level.

c. The vertical **POSITION** control is used to move the display up and down on the vertical axis. The position control has a positioning range of + and - one additional screen. This extra positioning range is useful for viewing the small details on the tops and bottoms of waveforms.

d. The **NORM/INVERT** switch determines the direction that a positive voltage will move the trace. In the **NORM** position, positive input voltages move the trace up on the face of the crt. In the **INVERT** position, positive input voltages move the trace down.

2-9 DUAL AND ADD OPERATION

Set controls as per initial set-up. Set **TIME/cm** to **1mSEC.** Position trace to upper half of the screen. Select Channel B and position trace to lower half of screen. Select **DUAL** mode. The upper and lower traces shall sweep simultaneously.

Set **TIME/cm** switch to **.5mSEC**. The upper and lower traces shall sweep simultaneously.

Set A and B **VOLTS/cm** to **2V/cm.** Connect the **PROBE CAL** to the A and B inputs. Set A **NORM/INVERT** switch to **INVERT**. Set to the **ADD** mode. The amplitude of the display should be less than 1cm.

2-10 OPERATION OF TRIGGERING CONTROLS

The nomenclature in the green shaded area on the front panel identify the controls which affect the triggering of the time-to-voltage or sweep generator. It is these controls and their associated circuitry that distinguish the triggered oscilloscope from the recurrent sweep type. An understanding of the **TRIGGERING** controls is essential for using the oscilloscope to its maximum capabilities.

The function of the trigger circuit is to initiate the sweep when the input voltage to the trigger amplifier crosses an adjustable level on a selected slope.

a. The **-/+** switch selects the slope on which the sweep will trigger. (Positive slopes are rising edges; negative slopes are falling edges.) See Figure 2-4.

b. The **LEVEL** control is rotated to select the voltage level at which the sweep starts. See Figure 2-4.

c. The **EXT/INT** switch determines which two signals are used as the trigger circuit input voltage. In the **INT** position, this signal is the same signal which is displayed on the crt face. This position is used for viewing most waveforms. In the **EXT** position, the input to the trigger circuitry is made accessible at the **EXT** jack. Signals which are applied to this input should be in the .5 to 5 volt range.

d. The **NORM/TV V/H** switch selects filters which are used in separating the vertical and horizontal sync pulses from a composite video waveform, and applying these pulses to the trigger amplifier. Because of the unique characteristics of the video waveform an active sync stripper is used. This circuit strips the most negative information from the video input signal. See Figure 2-5.

Because of this stripping function, the waveform must be applied with the sync at the most negative part of the waveform. With the switch in the **INT** mode this is accomplished by the trace invert switch. If the display on the crt is adjusted using the trace inverter switch so that the sync pulse points down, the signal applied to the sync stripper will be of the proper polarity. Hence whenever these positions are used the sync must be at the bottom of the waveform.

When using an external trigger for video signals, the sync tips must be the most negative part of the waveform for stable triggering.

NOTE

*Whenever the **TV V/H** position is used, the **AUTO/NORM** control should be moved to the **NORM** position.*

The **TIME/cm** switch automatically selects the proper video sync which corresponds to the sweep speed setting. (Vertical sync for sweep speeds of .2sec to .1msec and horizontal sync for 50μsec to .5μsec.)

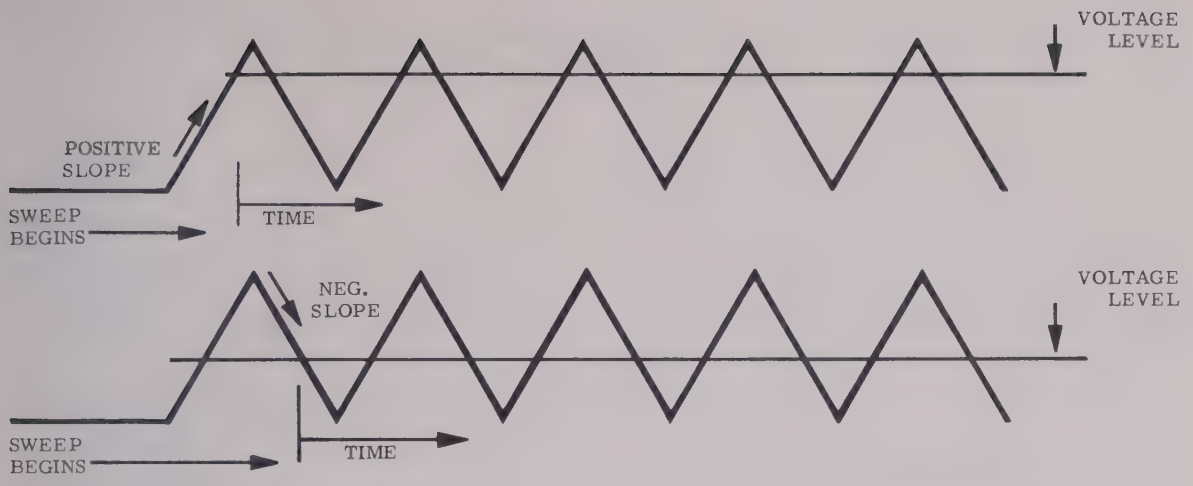


Figure 2-4. Positive and Negative Trigger Slopes

e. The **AUTO/NORM** switch in the **AUTO** position produces a trace in the absence of the trigger signal. It is useful for providing a baseline when there is no input signal to the oscilloscope. When an input signal of sufficient amplitude is applied to the trigger input, the auto circuit is automatically disabled. Whenever difficulty is experienced in triggering at low screen deflection, at frequencies below 20Hz, or on a very narrow pulse the **NORM** position should be used. The **NORM** position should be used for all video.

2-11 OPERATION OF THE HORIZONTAL CONTROLS

a. The horizontal **TIME/cm** switch determines the rate at which the spot moves across the face of the crt. With the **TIME/cm VARIABLE** control in the **CAL** position, the spot will move across the screen at a rate of .2sec/cm to .5μsec/cm in 18 calibrated ranges.

b. The **HORIZ GAIN** switch in the **X5** position produces approximately a 5 times faster sweep in each **TIME/cm** range.

c. The **TIME/cm VARIABLE** allows fine adjustment between these calibrated ranges and extends the slowest range to greater than 1sec/cm.

d. The **EXT HORIZ INPUT** is used when X vs Y measurements are made with the **TIME/cm** switch in **EXT HORIZ**. The **EXT** jack is dc coupled to the horizontal amplifier and an external capacitor should be used when dc blocking is needed.

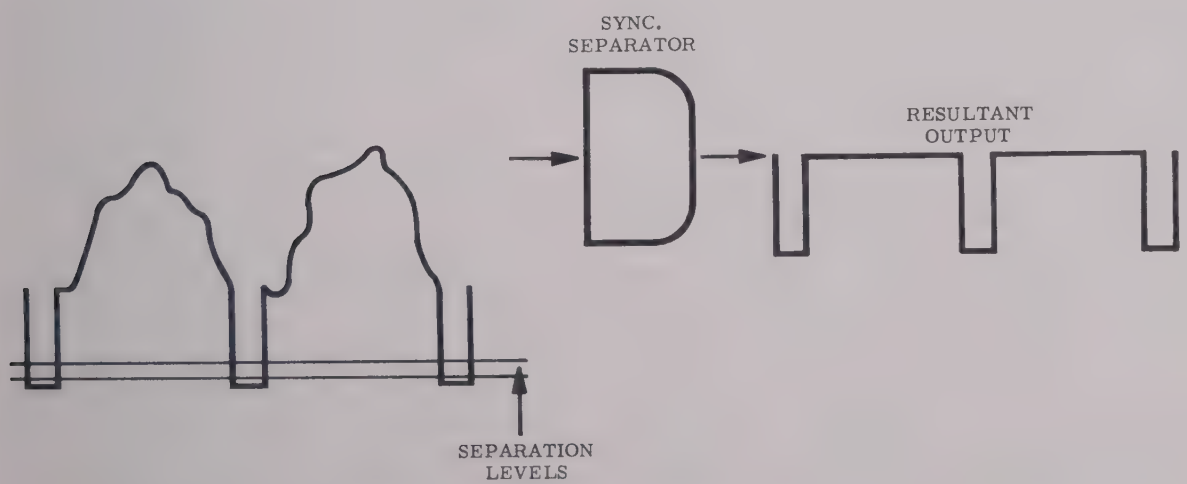


Figure 2-5. Action of Sync Stripper Circuit

SECTION III
APPLICATIONS

In this section of the instruction manual, the basic procedure and techniques for making measurements will be described. This is not meant to be a comprehensive text covering all possible uses of the oscilloscope but is intended to familiarize the user with some of the basic applications and techniques. Familiarity with the techniques and the operation of the controls will enable the operator to employ the instrument in a wide variety of applications.

3-1 TYPICAL VOLTAGE MEASUREMENTS

a. Ac Component Measurement

1. Set the vertical input selector switch to the **AC** position. In this position, only the ac components of the signal are displayed on the crt. (It should be noted, however, that if the frequency of the ac component is very low, the **DC** position should be used.) If the trace is off screen, use the vertical position control in conjunction with the **VOLTS/cm** switch to obtain a trace on screen.

2. To make peak to peak measurements of the ac component of the waveform, perform the following steps. The **AUTO** position should be used and the sweep set to **1ms/cm**, or some other more appropriate rate, dependent upon the frequency of the viewed waveform.

3. Adjust the **VOLTS/cm** switch for the largest on-screen display.

4. Adjust the **TIME/cm** so that several cycles of the waveform are displayed.

5. Use the vertical **POSITION** and horizontal **POSITION** controls to position the waveform to a point on the crt where the amplitude can be easily determined. As an example, position the waveform so that one of the negative peaks coincides with one of the lower horizontal graticule lines and the positive peak occurs on the divided center vertical line.

6. Measure the vertical deflection in centimeters and multiply this result by the **VOLTS/cm** setting (and by the probe attenuation factor, if used). As an example of this method, assume that 5.2 centimeters of deflection is obtained, that the **VOLTS/cm** switch is set to **.1 VOLTS/cm**, and that a 10:1 probe is used. The calculation of the voltage amplitude is as follows:

Vert. Defl. in cm	x	Vert. VOLTS/cm Setting	x	Probe Atten. Factor	=	Volts p-p
5.2	X	.1	X	10	=	5.2V p-p

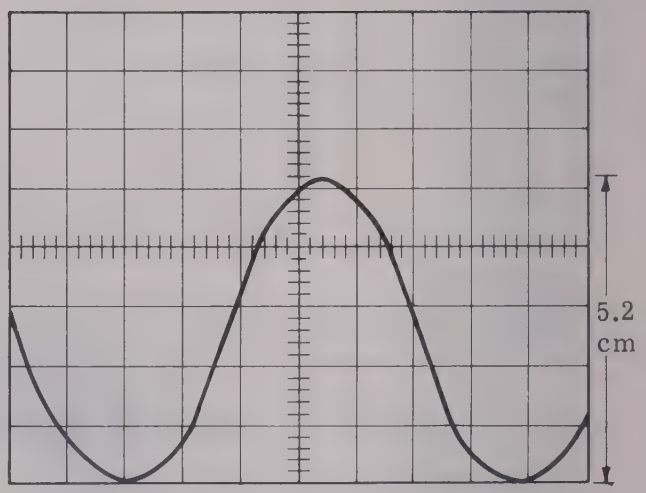


Figure 3-1. Measurement of AC Component Amplitude

b. Dc Level Measurements

1. Set the **TIME/cm** to **1μSEC/cm**. Depress **AUTO** button.

2. Adjust the **VOLTS/cm** switch so that the voltage applied to the input connector is no more than eight times the **VOLTS/cm** switch setting.

3. Set the **AC/DC/GND** switch to **GND**, and using the vertical **POSITION** control, position the trace so that it coincides with the bottom horizontal graticule line. This point will be used as the zero voltage reference. (Note that if the signal to be measured is negative, one of the top horizontal graticule lines should be used.) Do not move the vertical **POSITION** control after it has been set.

4. Set the **AC/DC/GND** switch to **DC**.

5. Adjust the **TIME/cm** and trigger controls for a stable trace if there is an ac component present.

6. Using the horizontal **POSITION** control, position the point on the waveform to be measured on the center vertical graticule line.

7. Measure the distance from the base reference line to the point on the waveform which crosses the center vertical graticule line and convert this reading to a voltage by the following relationship:

deflection in cm	x	vertical **VOLTS/cm** setting	x	probe attenuation factor	=	volts dc

3-2 TYPICAL TIME MEASUREMENTS

To measure the time duration of a pulse or the period of a waveform, the following procedure is used.

a. Measurement of Pulse Duration

Generally, when measuring the width of a pulse the measurement is made from the 10% of amplitude points. Since the procedure for measuring pulse width and pulse duration differ only in the reference point on the waveform, the more complex or pulse width measurement is outlined below.

1. Adjust the **VOLTS/cm** switch for a deflection near full scale and note the exact amplitude in division.

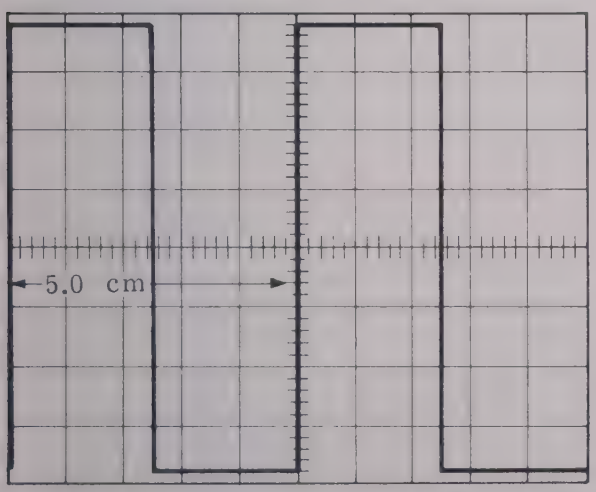
2. Divide this measurement by 10 and, using the vertical **POSITION** control, position the trace bottom exactly this amount under the center horizontal graticule line. As an example: assume that the deflection height is 4.5 centimeters. Dividing this by 10 yields .45 centimeters or 2-1/4 minor divisions. Position the bottom edge of the waveform this distance below the graticule horizontal center line. Do not adjust the vertical **POSITION** control after this point.

3. Set the **TIME/cm** switch so that the pulse width is no more than 10 times the **TIME/cm** switch setting.

4. Using the horizontal **POSITION** control, position the leading edge of the pulse to a convenient graticule line, at the point where it crosses the horizontal center line, at the left-hand side of the screen.

5. Measure the distance (in centimeters) between the point where the leading edge crosses the center horizontal graticule line and the trailing edge crosses the center horizontal graticule line.

6. Multiply this distance by the time indicated by the setting of the **TIME/cm** switch to obtain the pulse width in units of time.



T = 5.0cm x 1mSec/cm = 5.0 mSec

Figure 3-2. Measurement of Period Duration

b. Measuring the Period of Periodic Waveforms

1. Adjust the **VOLTS/cm** and vertical **POSITION** control to give a trace centered about the horizontal centerline of the graticule.

2. Adjust the sweep rate and trigger controls to obtain one or more cycles of the waveform on screen.

3. Using the horizontal **POSITION** control, position the waveform so that it crosses the junction point of a vertical graticule line on the left-hand side of the screen and center horizontal graticule line. Note the direction in which the waveform crosses the center horizontal graticule line.

4. Measure the distance (in centimeters) between the point where the leading edge crosses the center horizontal graticule line and the trailing edge crosses the center horizontal graticule line.

5. Multiply this distance by the setting of the **TIME/cm** switch to obtain the time duration of the period (T). This technique is demonstrated in Figure 3-2.

3-3 VIDEO SIGNAL MEASUREMENT

a. Set the **NORM/TV V/H** switch to **TV V/H**. Set **NORM/AUTO** switch to **NORM**.

b. Set **VOLTS/cm** for proper setting depending on the amplitude of signal to be viewed. Connect video to vertical input using a 10:1 (low cap) probe. Be sure the sync tips are pointing downward as the active sync stripper in the Model 517 will only trigger on negative going signals (refer to Figure 3-3).

c. Set the **TIME/cm** switch as follows:

1. FRAME (vertical) from **.2SEC** to **.1mSEC**. The scope will automatically trigger on the vertical sync on these ranges. The **TIME/cm** range can be selected for the amount of frame detail needed to be viewed. **5mSEC/cm** will display approximately 2 frames.

2. LINE (horizontal) from **50μSEC** to **.5μSEC**. The scope will automatically trigger on the horizontal sync on these ranges. The **TIME/cm** range can be selected for the amount of line detail needed to be viewed. **20μSEC/cm** will display approximately 3 lines.

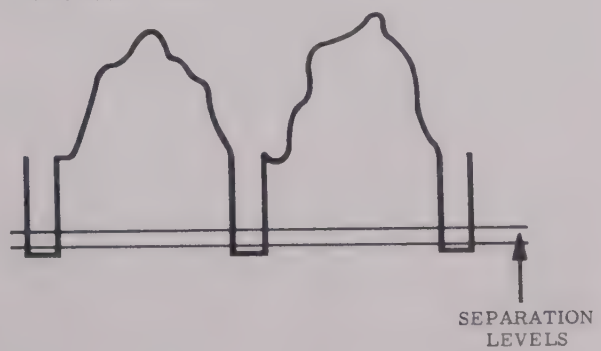


Figure 3-3. Direction of Applied Sync Pulses

3.4 OBSERVING MODULATED RF SIGNALS OVER 15MHz

The simplest way to observe a modulated waveform is with a detector probe (diode and capacitor combination) connected from the signal to the vertical input of the scope. The signal observed on the screen will be the modulating signal with the RF (carrier) removed.

The complete modulated signal (including RF) can be observed on the scope screen by connecting the signal to the vertical input usually through a high impedance low capacity probe.

If the RF or carrier of the modulated signal exceeds the 15MHz bandwidth of the scope, as with CB transmitters, the vertical final of the scope may flatten or distort the signal if the input amplitude is not kept to a minimum. This can be done by using the following procedure:

Set the trace to the middle of the screen. Connect transmitter or signal to be observed to the vertical input and adjust the **VOLTS/cm** switch for less than two cm of modulated signal on screen.

SECTION IV
THEORY OF OPERATION

4-1 POWER SUPPLY WITH BLANKING CIRCUIT (Refer to Figure 7-6)

a. General Description

The power supply is a line-operated, pre-regulated, ferrite transformer coupled, dc to ac inverter. Low voltage digital timing circuitry provides push-pull, 22,000 hertz, forced drive of a pair of power switching transistors connected to the transformer primary. Regulated operation is assured over input voltages from 105 to 125 volts ac rms, and 50 to 400 hertz, as well as dc voltages from 130 to 180 volts. Included within the power supply enclosure is the crt blanking circuit so that all connections to the crt excepting the connections to the deflection plates are made through the power supply. Input power draw is approximately 45 watts with 125 volts ac input. The other connections to the power supply include focus,astigmatism, and intensity controls, and the blanking input line. The earth ground wire (green wire of ac cord) runs with the output voltage wire to a front panel terminal strip, where the chassis, the earth ground wire, and the zero volt common wire are connected.

b. Line-Operated Pre-Regulator

The line voltage is full wave rectified with capacitors C104 and C109 providing line to earth transient suppression, thermister RT101 providing input current limiting, and capacitor C107 providing line to line transient suppression. The resultant dc voltage varies directly with the ac input line voltage from 130 to 175 volts dc. This voltage is then regulated to 123 volts dc by Q105 through Q102. Transistors Q101 and Q103 are darlington connected to Q102 and are current limited by the action of CR105, CR106, and R105 on Q103, and CR103, CR104, and R103 on Q101. Resistors R108, R104, and R102 tie down the bases of Q101, Q103, and Q102 respectively. Q104, CR107, R109, R107, and R110 comprise a foldback current limiter by robbing base drive to Q102. The limiter is designed to operate above 400 milliamps load current, and to foldback to less than 100 milliamps, when the output is shorted. Regulation is accomplished by comparison of a portion of the output voltage with a zener diode voltage reference CR124.

c. Inverter Drive Circuitry

The integrated circuit timer Z105 generates a digital pulse train with a repetition rate twice the inverter frequency, or 44,000 hertz. The pulse width is set for 4 microseconds during which the timer output is at logic zero or zero volts. This pulse width determines the dead time of the power switching transistors Q106 and Q107 where neither transistor is being driven. The timer output is coupled to a type D flip flop Z107 through one nor gate of Z103, connected as an inverter. The timer output also connects to two parallel connected inverters in integrated circuit Z101, whose output connects to two nor gates in Z103. The other inputs of these two nor gates connect to the complementary outputs of the flip flop Z107. The outputs of these two gates carry the push-pull driving signals, with dead time, to two sets of two parallel connected inverters in Z101. Transistor Q115 sources base current to power switching transistor Q106 while transistor Q116 sinks current from the base of transistor Q106. Since the base circuits for transistors Q115 and Q116 are connected together, only one of these transistors is on at any time. The other signal output from inverter Z101 similarly drives an identical push-pull circuit coupled to the other switching transistor Q107. Diodes CR126 and CR129 bias the emitters of transistors Q106 and Q107 to approximately 1.4 volts, so that one switching transistor is actually reversed biased to an off condition while the other one is saturated thus improving switching speed.

A snubbing type clamp circuit is formed from diodes CR110 and CR111, resistor R118, and capacitor C102. This circuit serves to limit peak voltage due to inductive kick of the primaries during switching transitions. Another snubbing circuit serves to delay the rise in collector voltage so that the collector current can fall to a low value. This circuit ensures operation of switching transistors Q106 and Q107 with their safe operating area by minimizing power peaks. The snubber for Q106 is formed from diode CR120, resistor R130, and capacitor C112. The snubber for Q107 is formed from diode CR121, resistor R131, and capacitor C113. Additional protection against inductive components of the secondary loading is provided by emitter to collector diodes CR125 and CR127. Voltage regulation for the inverter drive circuitry is provided by zener diode CR130 with bypass capacitors C114 and C115. Current is supplied to the zener diode from two different sources. During start up current is drawn from the 123 volt line through resistor R120, saturating transistor Q109, and drawing heavier current through resistor R119 to the zener diode CR130. Once the primary switching action begins, secondary voltage is supplied to the zener diode via diode CR113, capacitor C116, and resistor R125. At the same time, biasing of transistor Q110 shorts out the base of transistor Q109, preventing current flow from the 123 volt line through resistor R119. The inverter drive circuitry serves to alternately saturate switching transistors Q106 and Q107, thereby alternately impressing the 123 volt supply across the dual primary circuit. This primary squarewave alternation produces an alternating magnetic field within the ferrite transformer core, which links the transformer secondary windings. This alternating flux linkage induces stepped up or stepped down voltages in the secondaries by approximately 1.2 volts per turn.

Secondary voltages are +5 volts @ 65mA, +15 volts @ 150mA, -15 volts @ 150mA,+125 volts @ 95mA, +250 volts @ 25mA, -1900 volts @ 2mA, -150V @ 6mA (blanking) and 6.3 Vac @ 700mA (filaments). All of these voltages are regulated via the regulated +123 volt primary voltage. In addition, series dropping resistors and three terminal I. C. voltage regulators are used to further enhance regulation and overload protection of critical supplies.

The core of transformer T101 is connected to the common zero volt line of the secondary voltage outputs providing high isolation between the power line and output voltages to scope circuitry. All supply voltages used within the scope are therefore regulated and isolated from power line.

CAUTION

A power isolation transformer must be used between the power line and oscilloscope power supply under test when unisolated test equipment is used to analyze the primary side of the power supply circuitry due to direct power line rectification. Severe damage may result without ground isolation.

Line voltage is present on the power supply board, ON-OFF switch, and fuse. Extreme caution should be used when servicing this and any other electrical apparatus.

4-2 VERTICAL PREAMPS (Refer to Figure 7-7 or 7-8)

The A and B channel preamps are identical, with only one exception, the internal trigger pickoff which will be discussed later. Therefore any discussion of the A channel preamp can be applied to the B channel also.

Input signals from vertical input connector J201 are applied to the switch S201. In the **AC** position, signal-flow is through C209 eliminating dc levels. In the **DC** position, C209 is short circuited and the input is directly coupled to the **VOLTS/cm** attenuator.

In the .01, .02, and .05 volt positions of the vertical **VOLTS/cm** switch the unattenuated input signals are applied directly to the input of the vertical preamplifier at A. In the .1, .2, and .5 positions, the input signals are attenuated by a factor of 10 and applied to the preamplifier. The attenuation factor for the 1, 2, and 5 volt positions is 100 and for the 10, 20, and 50 positions the factor is 1000. Protection circuitry, between A input and the gate of field effect transistor Q205, prevents damage to Q205 under input overload conditions. CR201 is a special diode type featuring low leakage and low capacity.

Q205 is a dual field effect transistor which is stacked as a thermally balanced source follower. The DC Bal potentiometer adjusts the voltage at junction of R222 and Q206. This voltage is properly adjusted when voltages at the emitters of Q206 and Q210 are equal.

The gain of the 6 transistor differential cascode amplifier is determined by the resistors in the emitters of Q206 and Q210. In the .05, .5, 5, and 50 volt ranges, these are precision 1% resistors. In the .02, .2, 2, and 20 volt ranges, the gain is calibrated by R231 which is connected, by S202, in parallel with R248 and R249. Likewise in the highest gain settings (.01, .1, 1, 10), the gain is adjusted by R320. It is this gain changing used in conjunction with the decade attenuators which provide all 12 calibrated ranges.

AR201E serves as a current generator which fixes the total current flowing through the entire differential cascode amplifier. Positioning is accomplished by sinking current from one output and sourcing current into the other as the position pots R224 and R235 are set causing a corresponding shift in trace.

Polarity inversion is also accomplished in this stage. The outputs of AR201 A and C, and B and D are connected together respectively. Switch S203 is used to switch in and out a differential pair having opposite polarity signals at their emitter. The on pair allow the signal currents to flow into the loads.

4-3 VERTICAL SWITCHING (Refer to Figure 7-7 (Dual Trace Units Only)

The differential outputs from AR201 of channel A and AR202 of channel B are fed into a diode matrix. The matrix used in conjunction with the mode switch and the multivibrator of Q228 and Q229 selects which channel or channels are allowed to be fed into the vertical final drivers through the load resistors R260 and R261.

CR205 and CR206 are biased off and CR207 and CR208 are allowed to turn on with the mode switch in position **A** allowing the channel A signal to reach the drivers. The opposite happens when the mode switch is in position **B**.

The mode switch, in **DUAL**, with **TIME/cm** switch in positions **.2SEC** to **1mSEC**, biases the multivibrator into 100kHz, a stable condition allowing the A and B channel signals to appear at the drivers at 100kHz rate.

The mode switch, in **DUAL**, with **TIME/cm** switch in positions **.5mSEC** to **.5SEC**, biases the multivibrator into the bi-stable state which receives a trigger pulse at the end of each sweep through Q225. The bi-stable, in turn, biases each set of diodes on and off allowing channel A and B signals to alternately reach the drivers.

The mode switch, in **ADD**, biases both sides of the multivibrator off allowing CR207, CR208, CR209, and CR210 to turn on which passes both the A and B signals (as a composite) to the bases of the drivers.

4-4 VERTICAL FINAL (Refer to Figure 7-7 or 7-8)

The vertical final takes the voltage between the base of Q216 and Q217 and transforms it into a different current which flows through the final for a proper operating level at the collectors of Q207 and Q208.

The overall gain of the VERTICAL DRIVER - FINAL amplifier is adjusted by R252. The differential current signal developed by the drivers flows through Q207 and Q208 and develops a differential voltage across R206 and R209 which drives the crt. The inductors at the collectors of Q207 and Q208 match the output impedance of vertical final to the crt deflection plates giving an improved overall response.

4-5 TRIGGER PICKOFF (Refer to Figure 7-7) (Dual Trace Units Only)

The trigger signal is taken from the proper stage of the vertical amplifier and fed in the proper polarity to the input of the trigger amplifier Q421 for each setting of the **MODE** switch.

The trigger signal for **MODE** switch settings of **B** and **ADD** is picked off the vertical final driver stage through CR204 and fed through one of the analog gates in Z201 to the trigger amplifier. This gate is biased on by the **MODE** switch for only settings of **B** and **ADD**.

The trigger signal for the **MODE** switch settings of **A** and **DUAL** is taken from a differential amplifier made up of Q214 and Q215 in the A channel preamp. This amplified differential trigger signal is fed from the collectors of Q214 and Q215 to two analog gates of Z201. Each of these gates is controlled by the A polarity switch (S206) which in turn receives V1 (+15V) from the **MODE** switch. The polarity switch turns on the proper gate which lets one side of the other of the differential signal through to the trigger amplifier.

4-6 BLANKING CIRCUIT (Refer to Figure 7-6)

The blanking circuit is an edge triggered flip flop that controls the grid potential at the cathode ray tube. Triggering of this flip flop is accomplished through a coupling-pulse transformer. Pin 8 of nand gate Z402 is high whenever the horizontal circuitry is sweeping, and low when it is not. The pulse transformer differentiates these changes of state as shown in Figure 4-1.

Note that the pulses are positive going at the beginning of each sweep and negative going at the end. The pulses are applied to the bases of Q111 and Q113. Pulses which forward bias the base emitter junction of one of the stacked pair will automatically reverse bias the base emitter junction of the other. When Q111 conducts the voltage level reached at the crt grid (pin 2) is limited, due to the saturation of Q111, by the setting of the **INTENSITY** control.

It is the function of Q111 and Q113 to conduct heavily during the period when the pulses from T102 are applied to their bases. This causes the grid voltage to change state very rapidly. Once this new voltage level is reached, Q111 and Q113 cease conduction and the new voltage level is maintained by the output level of Q112.

Q114 and Q112 form a low power high voltage flip flop. Positive and negative pulses developed by Q111 and Q113 are coupled through R115 and C119 to the base of Q114. A positive pulse applied to the base of Q114 causes the voltage at the output of the flip flop, the collector of Q112, to go to the most positive state. Negative pulses at the base of Q114 cause this output voltage to change to the most negative state. This change of state is coupled through R136 and the secondary of T102 to hold the grid in either the high or low state.

4-7 TRIGGER AMPLIFIER (Refer to Figure 7-9)

The **INT/EXT** switch S406 selects one of the two possible trigger signals. The selected trigger is fed to the gate of Q421. Q421 serves as a source follower and signals at its gate are reproduced at R469. In all positions of the **INT/EXT** switch, these signals are connected to the base of Q419 in the Television Sync separator, and are also coupled through C426 and CR403 to the input of the trigger level comparator amplifier.

Input signals at the base of Q403 are compared to the dc voltage set by the level control, at the base of Q404. When the input signal swings more positive than this dc level, Q403 conducts while Q404 does not. This is shown in Figure 4-2 along with the resultant collector waveforms.

Because the trigger gate Z401 initiates the sweep only on positive slopes, negative slopes are turned into positive slopes at the collector of Q403. These two signals are then connected to S401, the -/+ switch. The selected signal is then amplified further by Q405 and Q406 and presented to the trigger gate, Z401.

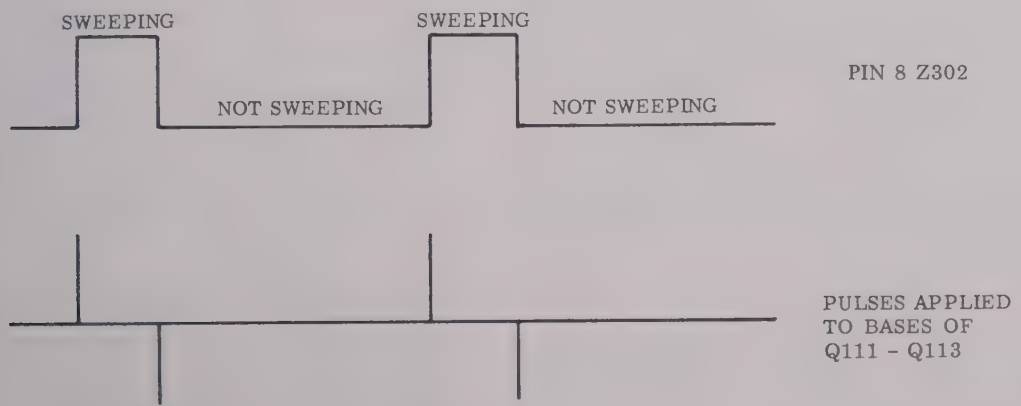


Figure 4-1. Blanking Control Pulse Waveform

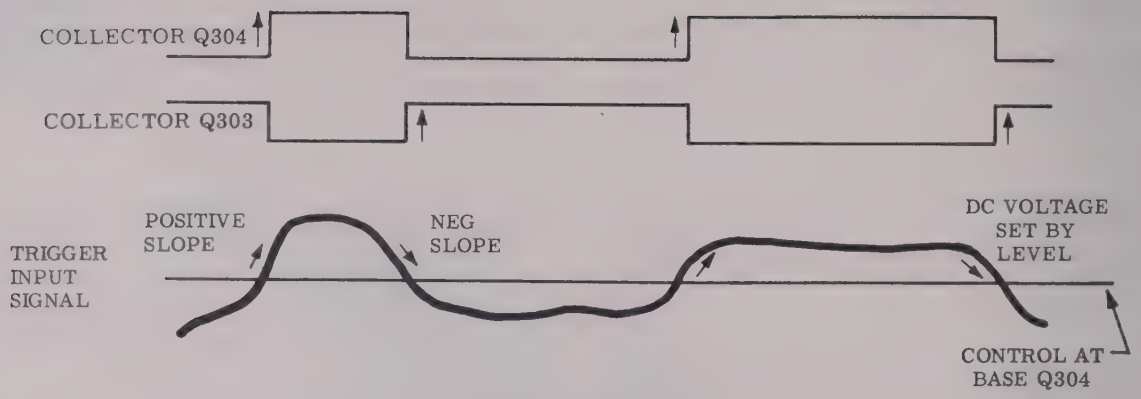


Figure 4-2. Trigger Amplifier Waveforms

4-8 AUTO GATE (Refer to Figure 7-9)

Q413 functions as the **AUTO** gate. In the **AUTO** mode, in the absence of a trigger signal, transistor Q413 is turned on through R401 and R436. This causes the collector of Q413 to be at approximately 0 volts. Pulses from unijunction oscillator Q414 are coupled into the emitter of Q413. These pulses cause Q413 to turn off. The collector then is at +15 volts during these pulses. The resultant collector pulses are then coupled through C412 into the base of Q402 and appear at the trigger gate.

When a trigger signal appears at the collector of Q403, this signal is rectified and filtered by CR406, CR407, and C415. This rectified, filtered, negative voltage causes Q413 to shut off and its collector rises. Under these conditions Q413 is off continuously and pulses from Q414 have no effect on the collector voltage. The trigger gate then acts on the input trigger signal and not on the auto pulses.

4-9 TRIGGER GATE (Refer to Figures 7-9 and 4-3)

In order to understand the operation of the trigger gate, the concept of hold off will be introduced. When the sweep is initiated by the trigger circuitry, no further trigger pulses are desired until the spot has been deflected horizontally across the crt and returned. A hold off signal is used to prevent triggering until some time after the spot has returned, otherwise, a trigger pulse could appear in the middle of the retrace of the spot, and sweep could start again in the middle of the display.

Two different transistors control hold off. Q416 causes hold off immediately after sweep is triggered and during the sweep interval. Q415 in conjunction with its series hold off timing capacitors C429 and C431 cause hold off during, and for a brief period after trace.

In order that the sweep starts at precisely the same point on the trigger waveform, a digital trigger gate is used. Trigger input signals are applied to pins 5 and 2 of Z401, and the hold off signal is applied to pin 10. When the hold off is low, pin 8 is high regardless of the state of the trigger input signal. After the hold off goes high, the trigger signal must go low, and on the next low to high transition, pin 3 of Z402 will go low. It is only when pin 3 goes low that the sweep is initiated.

4-10 SWEEP CIRCUIT (Refer to Figures 7-9 and 4-3)

The sweep circuitry used in this instrument relies on the fact that a fixed current into a capacitor produces a linear time-to-voltage ramping waveform. Q417 is a current generator and the magnitude of the current through its collector is determined by the voltage at the base, and the resistor in the emitter. By changing the resistor, 9 sweep ranges are produced for each sweep capacitor (C_T). Two different capacitors are used, C422 for the .2sec to .5msec ranges and C421 for the .2msec to .5sec ranges. Calibration of these sweep times for various capacitors is accomplished by adjusting the reference voltage at the base of Q417 with R457 and R458. The **TIME/cm VARIABLE** control R460 also varies this voltage to produce variable sweep times.

The current from Q417 can flow into one of two paths. When sweeping, Q418 is off and current flows in C_T. When not sweeping, Q418 is on and current flows into Q418.

When sweeping, the voltage across C_T is amplified by field effect transistor Q411 and transistor Q410. When the voltage at the collector of Q410 reaches the zener voltage of CR405, current begins to flow through the zener into the base of Q407. When Q407 conducts pin 1 of Z402 is pulled low. This causes the sweep set-reset-flip-flop output at pin 3 to go high which turns on Q418. This discharges C_T and returns the spot to the left side of the display to await the next trigger pulse into pin 5 of Z401.

4-11 TELEVISION SYNC SEPARATOR (Refer to Figure 7-9)

Transistor Q419 and Q420 form an active sync stripper. The action of this circuit is to separate signals which occur around the most negative level of the trigger input signal. When video signals of the proper polarity are applied, the sync pulses are at the most negative level. See Figure 2-5.

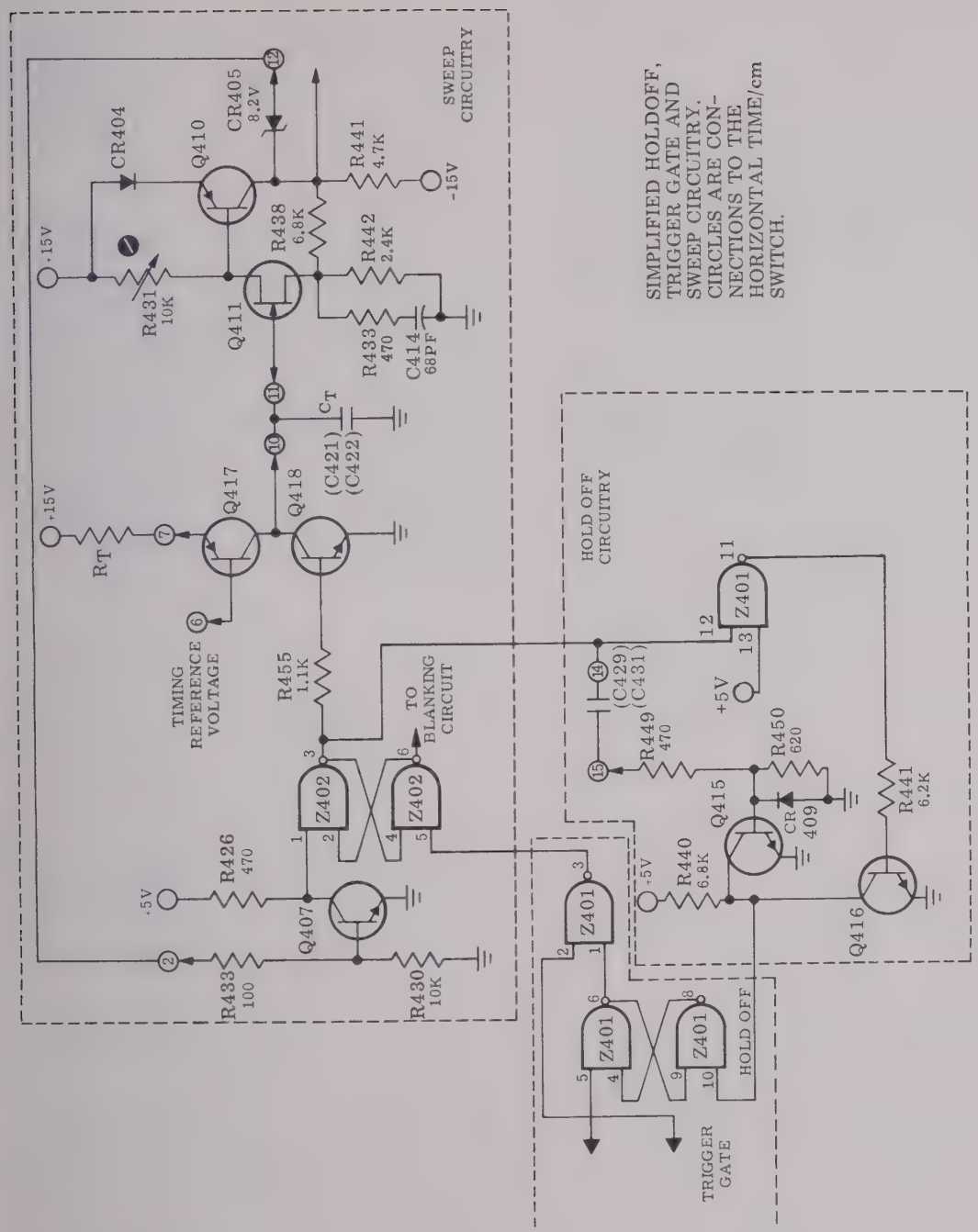


Figure 4-3. Simplified Diagram of Hold Off, Trigger Gate and Sweep Circuitry

A negative going edge applied to the base of Q419 causes this transistor to conduct which causes Q420 to conduct. As the collector of Q420 is pulled towards the -15 volt supply, diode CR412 begins to conduct. This causes the voltage on capacitor C420 to be pulled towards a level which tends to shut Q419 back off.

Equilibrium is reached when the final voltage on C420 is approximately .7 volts more positive than the most negative level of the input signal. When the input signal rises on a positive edge, Q419 and Q420 stop conducting immediately. This causes the collector voltage of Q420 to rise to approximately the +15V level. CR410 clamps this swing to approximately 5.8 volts. As soon as Q419 and Q420 cease conduction the voltage at the C420 – R454 junction begins to rise; however, this rate of rise is quite slow compared to the time between two sync pulses. Hence Q419 begins to conduct again on the next negative going edge and thus holds this capacitor voltage around the negative level of the input signal. Hence Q419 and thus Q420 can only conduct for voltages around the negative signal level. This effectively strips sync from video for a wide range of input amplitudes. The signal at the collector of Q420 is used as the TV H trigger signal. R448 and C417 serve as a low pass filter which separates the vertical sync pulse from the composite sync. This signal is the TV V trigger signal.

4-12 EXTERNAL HORIZONTAL SYSTEM (Refer to Figure 7-9)

Signals which are applied to **EXT HORIZ** jack are divided in amplitude by compensated divide R475, R476, C432, and C433. Signal input amplitude is determined by potentiometer R476, the **EXT HORIZ LEVEL** control. Input signals are amplified by Q411 and Q410 and then connected to the horizontal driver.

It is the function of this driver to transform the input voltage into a differential current which flows to the horizontal final amplifier. The total current through this stage is adjusted by R445. The overall X1 gain of the horizontal driver-horizontal final amplifier is determined by the emitter resistor R432 and R434. In the X5 position, these resistors are paralleled by R428 which increases the gain. Positioning of this stage is accomplished by changing the voltage at the base of Q409 which changes the ratio of the average current through Q408 and Q409. The signal current which is generated by the horizontal driver develops a voltage at the collectors of Q401 and Q402. The inductors L401, L402, and capacitors C403 and C404 are used to better match the amplifier to the horizontal deflection plates and improve the frequency response.

SECTION V
CALIBRATION PROCEDURE

The Hickok oscilloscope is designed to provide many years of stable, trouble-free operation. However, should it be necessary to replace any of the component parts, it is recommended that the overall calibration be checked and, if necessary, adjusted before attempting to use the instrument. Refer to figures 7-1 thru 7-5 for parts location.

5-1 CALIBRATION EQUIPMENT REQUIRED

a. Electronic multimeter (battery-operated preferred) capable of measuring 0 to 260 volts dc and 0 to 2 volts ac at 400Hz with an accuracy of ±1%. Hickok Model 3300B or equal.

b. Source of 20Hz and 20kHz squarewaves with a frequency accuracy of ±1%, or a source of broadcast video signals.

c. Source of 10kHz and 1MHz squarewaves.

d. Source of 400Hz sinewaves with adjustable output from .2 to 1.5 Vrms.

e. Low input capacitance voltage divider probe, Hickok Style 100-155 or equal.

5-2 POWER SUPPLY CALIBRATION

WARNING

The high-voltage power supply produces dangerous potentials in excess of 1900V. These voltages are present on the ***FOCUS*** *and* ***INTENSITY*** *control circuits behind the front panel, at the base of the cathode ray tube, and within the power supply itself.*

a. Remove the four corner trim strips by removing the eight corner screws and remove covers.

b. The low voltage power supplies are connected to a terminal strip near the front panel. The voltages at these terminals when measured with respect to chassis ground should be within the limits specified in Table 5-1.

Table 5-1. Voltage Limits for Low Voltage Supply

Wire Color	Voltage to Chassis Ground
Red-White	+240 to 260 Vdc
Orange-White	+120 to 128.5 Vdc
Red	+4.5 to +5.5 Vdc
Orange	+14.4 to +15.6 Vdc
Blue	−14.4 to −15.6 Vdc

c. If the terminal voltages are not within the specified limits proceed as follows:

1. A battery-operated multimeter capable of reading 123 volts to within ±0.5 volt is desired. If a battery-operated meter is not available, this calibration can be accomplished by using an isolation transformer between the power line and the oscilloscope.

2. Remove the screws which secure the power supply cover and remove the cover.

3. Adjust the multimeter to measure 123 volts dc and connect it across capacitor C111 of the power supply.

4. Turn the regulator adjust control R138 until the voltage across C104 reads 123 volts ±0.5 volt.

5. Measure the voltages again as in paragraph b. and Table 5-1.

5-3 HORIZONTAL PREAMPLIFIER CALIBRATION (Refer to Figure 7-4)

This adjustment controls the length of trace.

a. Set the **TIME/cm** switch in the **EXT HORIZ** position.

b. Adjust the horizontal preamp balance control R431 to obtain approximately 11cm trace length.

5-4 VERTICAL FINAL CURRENT ADJUST (Refer to Figure 7-5)

a. Set mode switch to **A**. Set the vertical **POSITION** control completely cw and use the multimeter to measure the voltage between the collector of vertical output transistor Q208 and chassis ground.

b. Adjust the vertical current limit control R270 for a reading of 24 volts ±0.5 volt and note this reading as voltage "A". The trace should be off screen.

c. Set the vertical **POSITION** control completely cw and measure the voltage from the other vertical output transistor Q207 to chassis ground and note this reading as voltage "B".

d. If voltage "B" is more positive than voltage "A", no further adjustment is required. However, if voltage "B" is less positive than "A", it will be necessary to reset the vertical current limit control R270 so that voltage "B" reads 24 volts ±0.5 volt. The trace should still be off screen.

e. Position the trace in the center of the screen and allow 15 minutes for stabilization.

f. Repeat the procedures in paragraphs 5-4a. through 5-4d. while checking voltages "A" and "B" on the collectors of Q208 and Q207 respectively and adjusting R270 as needed.

5-5 HORIZONTAL FINAL CURRENT ADJUST (Refer to Figure 7-4)

a. Make the following front panel control settings:

Control	Setting or Position
HORIZ GAIN switch	Set to **X5**
Vertical **POSITION** control	Set in center position
Horizontal **TIME/cm** switch	Set to **EXT HORIZ** input

b. Set the horizontal **POSITION** control completely cw and measure the collector to ground voltage of horizontal output transistor Q402.

c. Adjust the horizontal current limit control R445 for a reading of 40 volts ±2 volts and note this reading as voltage "C". The spot should be off screen.

d. Set the horizontal **POSITION** control completely cw and measure the collector to ground voltage of the other horizontal output transistor Q401 and note this as voltage "D".

e. If voltage "D" is more positive than voltage "C" adjust horizontal current limit control R445 so that voltage "D" reads 40 volts ±2 volts. The spot should still be off the screen.

5-6 SWEEP TIMING CALIBRATION (Refer to Figure 7-4)

a. Set front panel controls as follows:

Control	Setting or Position
Mode switch (517 only)	Set to **A**
A and B vertical input switches	Set to **DC**
A and B **VOLTS/cm** switches	Set to **.5**
EXT/INT switch	Set to **INT**
TV/NORM switch	Set to **NORM**
+/- switch	Set to **-**
AUTO/NORM switch	Set to **NORM**
HORIZ GAIN switch	Set to **X1**
TIME/cm switch	Set to **10mSEC**
A and **B VARIABLE** controls	Set to **CAL**
Horizontal **VARIABLE** control	Set to **CAL**

b. Connect a 20Hz squarewave signal to the vertical input connector of the oscilloscope and adjust the signal level for approximately 4 centimeters of deflection. Adjust the **TRIGGERING LEVEL** control for a stable display starting on a low level.

c. Adjust the sweep timing resistor R457 such that with the second falling edge on the 5th vertical graticule line of the cathode ray tube, the third falling edge is within ±1/4 of a minor division of the 10th vertical graticule line.

d. Connect a 20kHz squarewave signal to the vertical input connector and move the **TIME/cm** switch to **10μSEC.**

e. Adjust the sweep timing resistor R458 in the same manner as R457.

NOTE

The sweep timing can also be adjusted using video signals as a frequency source. The procedure is as outlined in the following subparagraphs.

f. Apply composite video signals to the vertical input connector of the oscilloscope and set triggering switch to **TV V/H**. With the **TIME/cm** switch in the **10mSEC** position, adjust R457 such that six vertical fields occupy 10 centimeters horizontally.

g. Move the **TIME/cm** switch to the **10μSEC** position. Adjust R458 such that one horizontal line occupies 63.5μsec.

5-7 VERTICAL AMPLIFIER GAIN ADJUST (Refer to Figure 7-2 or 7-3)

a. Connect a 400Hz sinewave signal to the vertical input connector and adjust triggering for a stable display.

b. Connect a multimeter or ac voltmeter having an accuracy of 1% or less across the vertical input to monitor the output of the sinewave generator.

c. Adjust the monitored voltage input to the oscilloscope to 1.414 Vrms. Set the **VOLTS/cm** switch at .5. Adjust R252 for exactly 8cm peak to peak deflection.

d. Adjust input voltage to 0.566 Vrms. Set the **VOLTS/cm** switch to **.2** and adjust R231 for exactly 8cm peak to peak deflection.

e. Adjust input to 0.283 Vrms. Set the **VOLTS/cm** switch at **.1** and adjust R320 for exactly 8cm peak to peak deflection.

f. Set mode switch to **B**. Connect 400Hz sinewave and meter to **B** input. Repeat steps c., d., and e. adjusting R304, R291, and R321 respectively.

5-8 ATTENUATOR COMPENSATION

a. Set the mode switch to **A**.

b. Connect a 10kHz squarewave signal to the A vertical input connector and adjust the trimmers for maximum

flatness of the squarewave display at the settings of the **VOLTS/cm** switch as listed below.

CHANNEL A Vertical VOLTS/cm Setting	Adjust	Note
.2	C220	Trimmers C201, C212, and C220 are located toward the rear of the A **VOLTS/cm** switch
2	C212	
10	C201	

c. Connect a 10:1 voltage divider probe (Hickok SP-7, SP-6 or equal) from the vertical input connector to the output of the squarewave generator. With the **VOLTS/cm** switch in the **.05** position, set the signal level for approximately full screen deflection and adjust the probe for maximum flatness of the squarewave.

d. Without disturbing the probe adjustment, move the **VOLTS/cm** switch to the setting listed below and adjust the corresponding trimmer capacitors for maximum flatness of the squarewave. Increase the squarewave generator output for usable deflection on each range.

CHANNEL A Vertical VOLTS/cm Setting	Adjust	Note
.2	C222	Trimmers C222, C217, and C202 are located toward the front of the vertical PC board
2	C217	
10	C202	

e. Set the mode switch to **B**, connect a 10kHz squarewave to the B vertical input connector, and adjust the trimmers for maximum flatness of the waveform using the following chart.

CHANNEL B Vertical VOLTS/cm Setting	Adjust	Note
.2	C244	Trimmers C244, C237, and C228 are located toward the front of the vertical PC board
2	C237	
10	C228	

f. Repeat steps c. and d. for channel B using the following chart.

CHANNEL B Vertical VOLTS/cm Setting	Adjust	Note
.2	C247	These trimmers are located toward the front of the B **VOLTS/cm** switch
2	C241	
10	C229	

5-9 CRT CAPACITY BALANCE AND INTENSITY LIMIT ADJUSTMENTS

The cathode ray tube capacity balance adjustment C211 and the intensity limit adjustment R115 are factory calibration controls which should not be tampered with in the field.

SECTION VI
SERVICING

6-1 GENERAL

Under normal operation conditions and with reasonable care this oscilloscope will provide trouble-free operation for extended periods of time with no other service than an occasional check and, if necessary, adjustment of the calibration circuits. If major repairs or adjustments become necessary they should only be undertaken by qualified persons who are thoroughly familiar with the operation of transistors and their associated circuitry.

The Hickok Electrical Instrument Company maintains a complete factory service department, supported by authorized factory repair stations, to ensure prompt and reliable service for all Hickok products. If major repairs or adjustments are needed, it is recommended that the equipment be returned for service.

Should it be necessary to repair the oscilloscope in the field, it is imperative that service personnel read and understand THEORY OF OPERATION and CALIBRATION PROCEDURE, Sections IV and V of this manual, before attempting to service the equipment.

It is important that a logical approach be used to localize circuit failures, as indiscriminate replacement of components could cause damage to the equipment or to perfectly good components. The procedure for replacing components in printed circuit boards outlined in Figure 6-1 should be followed rigorously in order to prevent damage to components or printed circuit boards.

6-2 PRECAUTIONS TO BE OBSERVED WHEN SERVICING THE OSCILLOSCOPE

WARNING

The high-voltage power supply produces dangerous potentials in excess of 2100V. These voltages are present on the ***FOCUS*** *and* ***INTENSITY*** *control circuits behind the front panel, on the blanking PC board at the base of the cathode ray tube, and within the power supply itself.*

CAUTION

Before removing the power supply from the oscilloscope for servicing, make sure that the line cord is disconnected from the power line. When servicing the power supply, an isolation transformer must be used between the power line and the oscilloscope to prevent dangerous electrical shock and destruction of components in the equipment.

6-3 SERVICING AND TROUBLESHOOTING PROCEDURES

a. Preliminary Test Procedure

When trouble develops check the obvious causes first, such as the following possibilities.

1. Be sure the line cord is plugged in and there is power at the receptacle.

2. Turn the **POWER** switch on. If the **POWER** indicator does not light, check for a blown fuse.

NOTE

A 1.5 ampere slow-blow fuse, F101, is mounted on bottom of rear panel.

3. Be sure all front panel controls are set properly for the desired operation and display.

b. Fault Isolation

The first step in repair of the unit should be to localize the problem to a general area of the circuitry, such as the vertical amplifier, trigger circuitry, etc. This can generally be accomplished by observation of the performance of the unit. As an aid to the localization of the problem area, it is helpful to think of the unit as divided into seven major areas of circuitry. These are as follows:

1. Trigger Circuitry
2. Sweep Generator
3. Blanking Circuit
4. External Horizontal Circuitry
5. Vertical Amplifier
6. Power Supplies
7. Calibrator

Adjust the panel controls through their range and observe the operation in an attempt to localize the problem to a particular section of the circuitry. The normal or abnormal operation of a particular control will aid in localizing the trouble.

The oscilloscope as with all highly accurate instruments will require periodic recalibration checks in order to ensure a high degree of accuracy. It also should be noted that, on occasion, circuits out of calibration may cause apparent trouble symptoms. For this reason, the calibration of the unit should be checked before proceeding with a detailed trouble analysis; also, a calibration check will greatly aid in localizing circuit failures. The calibration procedure is found in Section V of this instruction book.

After the trouble has been isolated to a particular circuit, perform a complete visual check of that circuit for faulty components. If a visual check of the circuit fails to detect the trouble, it will be necessary to check the circuit for its electrical operating characteristics.

When it has been ascertained that the unit requires repair, the first step is to measure the power supply voltages as described in the calibration procedure. Should any voltage read below its expected value by more than 10%, a shorted component should be suspected. The oscilloscope should be turned off and the short eliminated before further investigation. Operating the unit with a shorted supply can cause extensive damage to the power supply.

Since this oscilloscope is an extremely complex instrument, a comprehensive troubleshooting procedure is beyond the scope of the text. In general, troubleshooting an instrument can be divided into two parts: isolating or localizing the trouble to a particular circuit, and the actual location of the defective component. Reference to the following troubleshooting chart and to the theory of operation in Section IV will aid in localizing the trouble, and will help to correlate the symptoms of improper operation with the area of circuitry involved.

Table 6-1. Troubleshooting Chart

Symptoms	Possible Reasons	Components to be Checked
Pilot light does not light; unit does not operate	Blown fuse due to overload to supplies, improper line voltage	F101, RT101, C110, Q101 thru Q107, CR115 thru CR118
Pilot light lights, unit power supplies read 0, voltage across C111 is approximately 123 volts	Supply will not oscillate	T101, Q101 thru Q110, CR115 thru CR118
Power supply voltage to high R138 has no effect	Failure of series regulator or associated circuitry	Series regulator semiconductors Q105, Q101, Q103, CR124
Power supply voltages OK, no trace in any control position	Blanking circuit inoperative. Trace off screen due to amplifier failure. See Note 1, at end of table	Q111, Q113, Q112, Q114. Check components in vertical amplifier Q205 thru Q218, and horizontal amplifier components Q401 thru Q412
No triggering on **ENT/EXT** or LINE position. Trace appears in AUTO	Trigger amplifier failure	Q421, Q403, Q404, Q405
Poor or absent **TV V, TV H**	Sync separator failure	Q419, Q420, CR412, CR410
No **PROBE CAL** output	Defective **PROBE CAL** oscillator	Q422, Q423, Q424
Horizontal trace linearity poor at high sweep speeds	R445 out of calibration. Excessive horizontal driver current	Q412
Vertical distortion at high frequencies	R270 out of calibration. Excessive vertical driver current	Q218

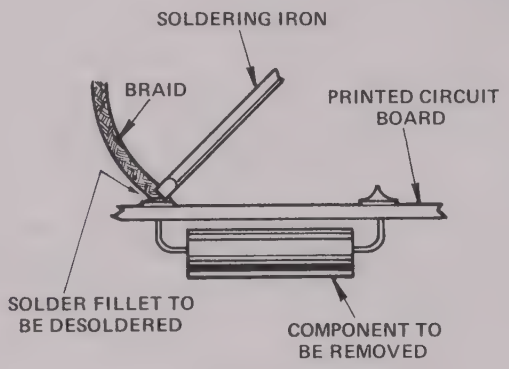
NOTE 1

In order to determine which if either amplifier has failed, perform the following test. Set controls as in paragraph 2-3. Connect a clip lead between the collectors of the two horizontal (Q401, Q402) or vertical (Q207, Q208) final amplifiers. These collectors are accessible at the tabs on the tops of the transistors. If shorting the vertical output transistor collectors together brings a trace on screen, then the vertical amplifier is at fault. If shorting the horizontal output transistor collectors together brings a spot onto the screen, then the horizontal amplifier has failed. ***CAUTION****: Connect the clip lead with the power off to avoid shock.*

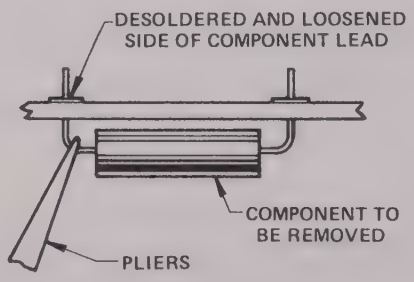
PROCEDURE FOR REPLACING COMPONENTS IN PRINTED CIRCUIT BOARDS

1. Place printed circuit in the horizontal position with the soldered side up*. Take a length of fine braid or fine stranded wire either tinned or not tinned. Braid is preferable. Dip the end of the braid in resin flux (London Chemical Co. type #77-33-TA or equivalent). Placed the fluxed end of the braid on a solder fillet of the component to be removed. Press the braid on to the fillet using the clean tip of the soldering iron. Do not overheat the board or component. Only heat the solder fillet sufficient to melt the solder. The solder will "wick" up the braided wire removing the solder from the joint. Continue this process until all leads of the component to be removed are free of solder.

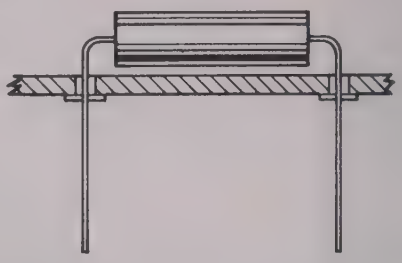
*A SOLDAPULLT desoldering tool, manufactured by Edsyn Inc., can be used in place of standard wire.



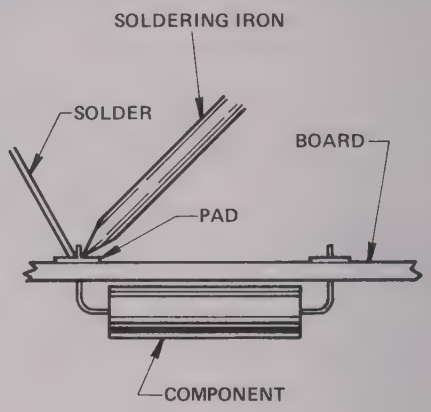
2. Using a pair of needle nose pliers "wiggle" each lead of the component to be removed to be sure it is free of the land area to which it was soldered. Place the needle nose pliers on the component lead and remove the lead. Continue the procedure with each component lead until the component is removed. Do not force the leads. If a lead can not be removed touch the lead on the soldered side of the board with the soldering tip.



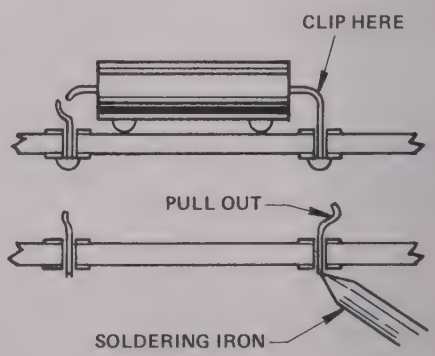
3. Bend clean tinned leads of new component and carefully insert in holes. (Do not force component. If it does not insert easily reheat pad and clean as before).



4. Hold part to board and solder leads from print side of board. Do not leave a large blob of solder on pad. The correct amount can be determined by observing other connections made in production.



Clean holes with a piece of .020 stainless steel wire by melting the solder and poking the wire through.'



The above should be carefully followed or extensive damage to the printed circuit board will result.

Figure 6-1. Servicing Etched Circuit Board

SECTION VII
PARTS LIST

When ordering parts be sure to give the reference designation, description, and the Hickok part number as listed in the following table. Unless otherwise indicated in the NOTES column, parts listed are applicable to all models. Also include the model and serial number of the equipment. There is a minimum billing charge of $25.00 for all parts orders.

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
AR201		INTEGRATED CIRCUIT: CA3086	9800-121
AR202	*	Same as AR201	
C101		CAPACITOR, FIXED, METALLIZED MYLAR: .22 uf, 250 volts	3090-104
C102		CAPACITOR, FIXED, METALLIZED POLYCARBONATE: .1 uf, 400 volts	3103-113
C103		CAPACITOR, FIXED, CERAMIC: .005 uf, 20%, 3KV, disc type	3110-281
C104		CAPACITOR, FIXED, CERAMIC: .01 uf, 1000 volts, disc type	3110-341
C105		CAPACITOR, FIXED, POLYESTER FILM: .1 uf, 20%, 3000 volts	3103-67
C106		CAPACITOR, FIXED, ELECTROLYTIC: 2.5 uf, 350 volts	3085-475
C107		Same as C101	
C108		CAPACITOR, FIXED, METALLIZED MYLAR: .047 uf, 250 volts	3090-102
C109		Same as C104	
C110		CAPACITOR, FIXED, ELECTROLYTIC: 220 uf to 250 uf, 200 volts	3085-553
C111		CAPACITOR, FIXED, METALLIZED POLYESTER FILM: 2.2 uf, 10%, 200 volts	3092-229
C112		CAPACITOR, FIXED, CERAMIC: disc type, 2200 pf	3111-524
C113		Same as C112	
C114		CAPACITOR, FIXED, DISC CERAMIC: .1 uf, 25 volts	3110-333
C115		CAPACITOR, FIXED, ELECTROLYTIC: 68 uf, +50% -10%, 6.3 volts	3085-435
C116		CAPACITOR, FIXED, ELECTROLYTIC: 47 uf, +50% -10%, 25 volts	3085-449
C117		Same as C106	
C118		CAPACITOR, FIXED, ELECTROLYTIC: 16 uf, 200 volts	3085-477
C119		CAPACITOR, FIXED, CERAMIC: disc type, 33 pf, 20%, 500 volts	3111-513
C120		Same as C116	
C121		Same as C114	
C122		CAPACITOR, FIXED, CERAMIC: disc type, 680 pf, 20%, 500 volts	3111-521
C123		Same as C116	
C124		Same as C114	
C125 thru C127		Same as C122	
C128		Same as C116	
C129		Same as C114	
C130		CAPACITOR, FIXED, DIPPED MICA: 470 pf, 5%, 500 volts	3096-541
C131		CAPACITOR, FIXED, DISC CERAMIC: .01 uf, 25 volts	3110-332
C132		CAPACITOR, FIXED, ELECTROLYTIC: 680 uf, +50% -10%, 16 volts	3085-446
C133		Same as C132	
C134		CAPACITOR, FIXED, CERAMIC: disc type, .1 uf, 500 volts	3110-69
C201		CAPACITOR, VARIABLE: .7-3 pf trimmer	3115-85
C202		CAPACITOR, VARIABLE: .7-6 pf trimmer	3115-86
C203		CAPACITOR, FIXED, COMPOSITION: 8 pf, 10%, 500 volts	3116-18
C204		CAPACITOR, FIXED, POLYSTYRENE: 1800 pf, 63 volts	3103-125
C205		CAPACITOR, FIXED, CERAMIC: 150 pf, 20%, 500 volts	3111-517
C206		CAPACITOR, FIXED, METALLIZED MYLAR: .1 uf, 250 volts	3090-103
C207		CAPACITOR, FIXED, COMPOSITION: 3.9 pf, 10%, 500 volts	3116-20
C208		Same as C207	

*** Models 517 and 5315 only**

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
C209		CAPACITOR, FIXED, METALLIZED POLYCARBONATE: .1 uf, 630 volts	3092-613
C210		CAPACITOR, VARIABLE: 10-60 pf trimmer	3115-98
C211		Same as C201	
C212		Same as C201	
C213		Same as C210	
C214		CAPACITOR, FIXED, CERAMIC: disc type, 1000 pf, +50% -20%, 500 volts	3111-522
C215	*	CAPACITOR, FIXED: calibration, value determined in production	
C216		CAPACITOR, FIXED, CERAMIC: disc type, 100 pf, 20%, 500 volts	3111-516
C217		Same as C202	
C218		Same as C203	
C219		CAPACITOR, FIXED, DIPPED MICA: 220 pf, 5%, 500 volts	3096-533
C220		Same as C201	
C221		Same as C210	
C222		Same as C202	
C223		Same as C203	
C224		CAPACITOR, FIXED, DIPPED MICA: 27 pf, 5%, 500 volts	3096-511
C225		CAPACITOR, FIXED, ELECTROLYTIC: tantalum, 1 uf, 35 volts	3085-433
C226	*	Same as C215	
C226	**	CAPACITOR, FIXED, CERAMIC: disc type, 15 pf, 500 volts	3111-511
C227		Same as C225	
C228	*	Same as C201	
C229	*	Same as C202	
C230	*	Same as C203	
C231	*	Same as C204	
C232	*	Same as C205	
C233	*	Same as C209	
C234	*	CAPACITOR, FIXED, ELECTROLYTIC: bead tantalum, 10 uf, 25 volts	3085-480
C235	*	Same as C210	
C236	*	Same as C210	
C237	*	Same as C201	
C238	*	Same as C214	
C239	*	Same as C215	
C240	*	Same as C122	
C241	*	Same as C202	
C242	*	Same as C203	
C243	*	Same as C219	
C244	*	Same as C201	
C245	*	Same as C210	
C246	*	CAPACITOR, FIXED, METALLIZED MYLAR: .022 uf, 250 volts	3090-108
C247	*	Same as C202	
C248	*	Same as C203	
C249	*	Same as C224	
C250	*	Same as C225	
C251	*	Same as C225	
C252		Same as C234	
C253	*	Same as C226	
C254	*	Same as C226	
C255	*	Same as C226	
C302	***	Same as C119	

* Models 517 and 5315 only
** Models 515, 5015, and 5015LD only
*** Model 5015 only

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
C401		Same as C131	
C402		Same as C234	
C403		CAPACITOR, FIXED, COMPOSITION: 5 pf, 10%, 500 volts	3116-17
C404		Same as C403	
C405		Same as C131	
C406		Same as C131	
C407		Same as C206	
C408		Same as C225	
C409		CAPACITOR, FIXED, CERAMIC: disc type, 47 pf, 20%, 500 volts	3111-514
C410		CAPACITOR, FIXED, METALLIZED POLYCARBONATE: .47 uf, 10%, 100 volts	3103-108
C411		Same as C234	
C412		Same as C216	
C413		Same as C114	
C414		CAPACITOR, FIXED, CERAMIC: disc type, 68 pf, 20%, 500 volts	3111-515
C415		Same as C234	
C416		Same as C214	
C417		CAPACITOR, FIXED, DISC CERAMIC: .02 uf, 25 volts	3110-361
C418 thru C420		Same as C234	
C421		CAPACITOR, FIXED, POLYSTYRENE: 2200 pf, 5%, 125 volts	3103-107
C422		CAPACITOR, FIXED, METALLIZED POLYESTER FILM: 2.2 uf, 100 volts	3103-105
C423		Same as C114	
C424		CAPACITOR, FIXED, CERAMIC: disc type, 220 pf, 20%, 500 volts	3111-518
C425		CAPACITOR, FIXED, CERAMIC: disc type, 22 pf, 20%, 500 volts	3111-512
C426		Same as C234	
C427		Same as C234	
C428		Same as C206	
C429		CAPACITOR, FIXED, ELECTROLYTIC: 4.7 uf, 35 volts	3085-481
C430		Same as C425	
C431		CAPACITOR, FIXED, POLYSTYRENE: 3300 pf, 63 volts	3103-126
C432		Same as C119	
C433		CAPACITOR, FIXED, CERAMIC: disc type, 330 pf, 20%, 500 volts	3111-519
C434		Same as C414	
C435		CAPACITOR, FIXED, METALLIZED MYLAR: .01 uf, 250 volts	3090-101
C436		Same as C435	
C437		Same as C234	
C438		Same as C234	
C439		Same as C131	
CR101		SEMICONDUCTOR DEVICE: diode 1N4004	3870-300
CR102		Same as CR101	
CR103		SEMICONDUCTOR DEVICE: diode 1N914	3870-175
CR104 thru CR107		Same as CR103	
CR108		SEMICONDUCTOR DEVICE: diode 400 volts, 1 amp, fast recovery, RC40	3870-403
CR109		Same as CR101	
CR110		Same as CR108	
CR111		Same as CR108	
CR112		Same as CR103	
CR113		SEMICONDUCTOR DEVICE: diode 100 volts, 1 amp, fast recovery, RC10	3870-402

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
CR114		SEMICONDUCTOR DEVICE: diode, high voltage, 25 ma, DL800	3870-404
CR115		SEMICONDUCTOR DEVICE: 1N5625, 400 volts, 3 amps	3870-345
CR116 thru CR118		Same as CR115	
CR119		Same as CR103	
CR120		Same as CR108	
CR121		Same as CR108	
CR122		SEMICONDUCTOR DEVICE: 600 volts, fast recovery rectifier diode, RC60	3870-407
CR123		Same as CR114	
CR124		SEMICONDUCTOR DEVICE: diode 1N5749B, 36 volts	3870-318
CR125		Same as CR108	
CR126		SEMICONDUCTOR DEVICE: diode 1N4001	3870-229
CR127		Same as CR108	
CR128		Not used	
CR129		Same as CR126	
CR130		SEMICONDUCTOR DEVICE: diode 1N5729B, 5.1 volts, ±5%	3870-320
CR131		Same as CR108	
CR132 thru CR134		Same as CR113	
CR201		SEMICONDUCTOR DEVICE: diode FD333	3870-332
CR202		Same as CR103	
CR203		SEMICONDUCTOR DEVICE: zener diode 1N5731B, 6.2 volts, ±5% 400 MW	3870-302
CR204		Same as CR103	
CR205 thru CR212	*	Same as CR103	
CR213	*	Same as CR201	
CR214	*	Same as CR103	
CR215	*	Same as CR203	
CR216	*	Same as CR103	
CR217	*	Same as CR103	
CR218	*	SEMICONDUCTOR DEVICE: diode 1N5736B, 10 volts, ±5%	3870-319
CR219	*	Same as CR103	
CR220	*	Same as CR103	
CR401		Same as CR126	
CR402		Same as CR126	
CR403		Same as CR103	
CR404		Same as CR103	
CR405		SEMICONDUCTOR DEVICE: 1N5734B, 8.2 volts, ±5%	3870-312
CR406 thru CR409		Same as CR103	
CR410		Same as CR130	
CR411		Same as CR103	
CR412		Same as CR103	
CR413		Same as CR218	
CR414 thru CR417		Same as CR103	

*** Models 517 and 5315 only**

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
DL301	***	DELAY LINE	4115-12
DS101		LAMP ASSEMBLY: NE-2	12270-60
F101		FUSE: 1.5 amp, slo-blo, 250 volts	6900-88
J201		CONNECTOR: coaxial type BNC, UG-1094/U	3475-303
J202	*	Same as J201	
J401		Same as J201	
J402		Same as J201	
J403		JACK: red nylon body	10300-55
L201		COIL: 3.3 uH	3320-412
L202		Same as L201	
L203		COIL: 10 uH	3320-387
L204		Same as L203	
L205		COIL: 1 mH	3320-372
L206		COIL: 1.5 uH	3320-408
L207		Same as L206	
L208		Same as L205	
L209 thru L211	*	Same as L205	
L401 thru L404		Same as L205	
P101		CORD: line, 6 ft, grey	3675-49
Q101		TRANSISTOR: MPSA-43, NPN, high voltage	20861-388
Q102		TRANSISTOR: MJ413, NPN, silicon, high power	20861-201
Q103		TRANSISTOR: MPS-U 10, silicon	20861-426
Q104		Same as Q101	
Q105		Same as Q101	
Q106		TRANSISTOR: 2N4240, NPN	20861-385
Q107		Same as Q106	
Q108		Not used	
Q109		Same as Q101	
Q110		TRANSISTOR: MPS 6560, silicon, NPN	20861-420
Q111		Same as Q101	
Q112		TRANSISTOR: 2N5828, NPN, silicon, high beta	20861-316
Q113		TRANSISTOR: 2N4888, PNP, silicon, high voltage	20861-182
Q114		Same as Q101	
Q115		TRANSISTOR: 2N3906, PNP, silicon	20861-412
Q116		Same as Q110	
Q117		Same as Q115	
Q118		Same as Q110	
Q201 thru Q204		Not used	
Q205A, B		TRANSISTOR: E420 dual matched FETS	20861-425
Q206		TRANSISTOR: selected (2N3563)	20861-331
Q207		TRANSISTOR: D40P1, NPN, silicon	20861-325
Q208		Same as Q207	
Q209		Not used	
Q210		TRANSISTOR: 2N3563, NPN, silicon	20861-196
Q211		Same as Q115	

*** Models 517 and 5315 only**

***** Model 5015 only**

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
Q212		Same as Q115	
Q213		Not used	
Q214	*	TRANSISTOR: 2N5130, NPN	20861-171
Q215	*	Same as Q214	
Q216		Same as Q210	
Q217		Same as Q210	
Q218		TRANSISTOR: 2N3566, NPN, silicon	20861-122
Q219 thru Q222		Not used	
Q223A, B	*	Same as Q205A,B	
Q224	*	Same as Q206	
Q225	*	TRANSISTOR: BC309, PNP, silicon, general purpose	20861-321
Q226		Not used	
Q227	*	Same as Q210	
Q228	*	Same as Q225	
Q229	*	Same as Q225	
Q301	***	TRANSISTOR: 2N5139, PNP	20861-181
Q302	***	Same As Q301	
Q303	***	Same as Q214	
Q304	***	Same as Q214	
Q401		TRANSISTOR: D40N1, NPN, silicon	20861-324
Q402		Same as Q401	
Q403		Same as Q206	
Q404		Same as Q210	
Q405		Same as Q301	
Q406		Same as Q301	
Q407 thru Q409		Same as Q112	
Q410		Same as Q301	
Q411		TRANSISTOR: 2N5245 N Channel FET	20861-185
Q412		Same as Q112	
Q413		Same as Q112	
Q414		TRANSISTOR: 2N4870, silicon, unijunction	20861-144
Q415		Same as Q112	
Q416		Same as Q112	
Q417		TRANSISTOR: EN3962, PNP, silicon	20861-322
Q418		TRANSISTOR: 2N5134, NPN, silicon	20861-323
Q419		Same as Q225	
Q420		Same as Q112	
Q421		Same as Q411	
Q422		Same as Q112	
Q423		Same as Q112	
Q424		Same as Q225	
R101		RESISTOR, FIXED, COMPOSITION: 47K ohms, 5%, 1 watt	18423-471
R102		RESISTOR, FIXED, DEPOSITED CARBON: 100K ohms, 5%, 1/4 watt	18470-104
R103		RESISTOR, FIXED, DEPOSITED CARBON: 150 ohms, 5%, 1/4 watt	18470-151
R104		RESISTOR, FIXED, DEPOSITED CARBON: 15K ohms, 5%, 1/4 watt	18470-153
R105		RESISTOR, FIXED, DEPOSITED CARBON: 18 ohms, 5%, 1/4 watt	18470-180
R106		RESISTOR, FIXED, WIRE WOUND: 1.5 ohms, 5%, 3 watt	18575-763

* Models 517 and 5315 only

*** Model 5015 only

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R107		RESISTOR, FIXED, DEPOSITED CARBON: 5.1K ohms, 5%, 1/4 watt	18470-512
R108		RESISTOR, FIXED, DEPOSITED CARBON: 1K ohms, 5%, 1/4 watt	18470-102
R109		RESISTOR, FIXED, DEPOSITED CARBON: 120K ohms, 5%, 1/4 watt	18470-124
R110		RESISTOR, FIXED, COMPOSITION: 16 ohms, 5%, 2 watt	18430-161
R111		RESISTOR, FIXED, DEPOSITED CARBON: 470 ohms, 5%, 1/4 watt	18470-471
R112		RESISTOR, FIXED, DEPOSITED CARBON: 20K ohms, 5%, 1/4 watt	18470-203
R113		RESISTOR, VARIABLE: 50K ohms, 30%, 1 watt (intens.)	16925-906
R114		Same as R104	
R115		RESISTOR, VARIABLE: 100K ohms, 1/4 watt	16925-737
R116		Same as R102	
R117		RESISTOR, FIXED, METAL FILM: 100K ohms, 1%, 1/4 watt	18555-37
R118		RESISTOR, FIXED, COMPOSITION: 100K ohms, 10%, 1 watt	18424-102
R119		RESISTOR, FIXED, WIRE WOUND: 5K ohms, 5%, 3-1/4 watt	18575-745
R120		RESISTOR, FIXED, COMPOSITION: 33K ohms, 10%, 1 watt	18423-332
R121		Not used	
R122		RESISTOR, FIXED, DEPOSITED CARBON: 2.2K ohms, 5%, 1/4 watt	18470-222
R123		RESISTOR, FIXED, COMPOSITION: 300K ohms, 5%, 1 watt	18424-301
R124		RESISTOR, FIXED, METAL FILM: 40.2K ohms, 1%, 1/4 watt	18554-74
R125		RESISTOR, FIXED, COMPOSITION: 56 ohms, 5%, 1/2 watt	18410-561
R126		RESISTOR, VARIABLE: 100K ohms, 30%, 1/2 watt (astig.)	16925-907
R127		RESISTOR, VARIABLE: 300K ohms, 30%, 1 watt	16925-908
R128		Same as R102	
R129		RESISTOR, FIXED, DEPOSITED CARBON: 43K ohms, 5%, 1/4 watt	18470-433
R130		RESISTOR, FIXED, COMPOSITION: 2.2K ohms, 10%, 2 watt	18432-222
R131		Same as R130	
R132		Same as R122	
R133		RESISTOR, FIXED, DEPOSITED CARBON: 100 ohms, 5%, 1/4 watt	18470-101
R134		RESISTOR, FIXED, COMPOSITION: 470K ohms, 5%, 2 watt	18434-471
R135		Same as R134	
R136		RESISTOR, FIXED, DEPOSITED CARBON: 680K ohms, 5%, 1/4 watt	18470-684
R137		RESISTOR, FIXED, DEPOSITED CARBON: 3 megohms, 5%, 1/4 watt	18470-305
R138		RESISTOR, VARIABLE: cermet, 5K ohms, 20%, 1/2 watt	16925-902
R139		RESISTOR, FIXED, DEPOSITED CARBON: 39K ohms, 5%, 1/4 watt	18470-393
R140		RESISTOR, FIXED, DEPOSITED CARBON: 15 ohms, 5%, 1/4 watt	18470-150
R141		RESISTOR, FIXED, DEPOSITED CARBON: 13K ohms, 5%, 1/4 watt	18470-133
R142		RESISTOR, FIXED, DEPOSITED CARBON: 470K ohms, 5%, 1/4 watt	18470-474
R143		Same as R129	
R144		Same as R112	
R145		RESISTOR, FIXED, COMPOSITION: 100 ohms, 10%, 1/2 watt	18411-102
R146		RESISTOR, FIXED, DEPOSITED CARBON: 1.5K ohms, 5%, 1/4 watt	18470-152
R147		RESISTOR, FIXED, DEPOSITED CARBON: 82 ohms, 5%, 1/4 watt	18470-820
R148		Same as R145	
R149		Same as R146	
R150		Same as R146	
R151		RESISTOR, FIXED, METAL FILM: 38.3K ohms, 1%, 1/4 watt	18555-244
R152		Same as R147	
R153		RESISTOR, FIXED, DEPOSITED CARBON: 8.2K ohms, 5%, 1/4 watt	18470-822
R154		Same as R146	
R155		RESISTOR, FIXED, DEPOSITED CARBON: 560 ohms, 5%, 1/4 watt	18470-561
R156		Same as R102	
R201		RESISTOR, FIXED, METAL FILM: 1 megohm, 1%, 1/4 watt	18555-35
R202		RESISTOR, FIXED, METAL FILM: 1K ohms, 1%, 1/8 watt	18554-125
R203		RESISTOR, FIXED, DEPOSITED CARBON: 2.4K ohms, 5%, 1/4 watt	18470-242
R204		Same as R203	

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R205		RESISTOR, FIXED, WIRE WOUND: 180 ohms, 10%, 5 watt	18575-765
R206		RESISTOR, FIXED, METAL OXIDE: 1K ohm, 5%, 10 watt	18575-762
R207		RESISTOR, FIXED, DEPOSITED CARBON: 24K ohms, 5%, 1/4 watt	18470-243
R208		Same as R207	
R209		Same as R206	
R210		RESISTOR, FIXED, DEPOSITED CARBON: 10 ohms, 5%, 1/4 watt	18470-100
R211		RESISTOR, FIXED, DEPOSITED CARBON: 6.2K ohms, 5%, 1/4 watt	18470-622
R212		Same as R211	
R213		RESISTOR, FIXED, DEPOSITED CARBON: 4.7K ohms, 5%, 1/4 watt	18470-472
R214		Same as R207	
R215		Same as R213	
R216		Same as R103	
R217		Same as R133	
R218		RESISTOR, FIXED, DEPOSITED CARBON: 3.6K ohms, 5%, 1/4 watt	18470-362
R219		RESISTOR, FIXED, DEPOSITED CARBON: 33 ohms, 5%, 1/4 watt	18470-330
R220		Same as R219	
R221		Same as R108	
R222		Same as R103	
R223		RESISTOR, FIXED, DEPOSITED CARBON: 300 ohms, 5%, 1/4 watt	18470-301
R224A, B		RESISTOR, VARIABLE: dual front and rear, 5K ohms, 30%, 1/2 watt	16925-904
R225		RESISTOR, FIXED, DEPOSITED CARBON: 10K ohms, 5%, 1/4 watt	18470-103
R226		RESISTOR, FIXED, DEPOSITED CARBON: 4.7 ohms, 1%, 1/4 watt	18555-80
R227		Same as R226	
R228		RESISTOR, FIXED, METAL FILM: 990K ohms, 1%, 1/4 watt	18555-112
R229		RESISTOR, FIXED, METAL FILM: 10.1K ohms, 1%, 1/8 watt	18554-129
R230		RESISTOR, FIXED, COMPOSITION: 330K ohms, 10%, 1/2 watt	18414-332
R231		RESISTOR, VARIABLE: 470 ohms, 20%, .1 watt	16925-903
R232		Not used	
R233		RESISTOR, VARIABLE: 2.5K ohms, p/o S202	
R234		Same as R219	
R235		Same as R218	
R236		RESISTOR, FIXED, DEPOSITED CARBON: 47K ohms, 5%, 1/4 watt	18470-473
R237		RESISTOR, FIXED, DEPOSITED CARBON: 24 ohms, 5%, 1/4 watt	18470-240
R238		RESISTOR, FIXED, DEPOSITED CARBON: 6.8K ohms, 5%, 1/4 watt	18470-682
R239		Same as R133	
R240		Same as R103	
R241		Same as R103	
R242		RESISTOR, FIXED, DEPOSITED CARBON: 330 ohms, 5%, 1/4 watt	18470-331
R243		RESISTOR, FIXED, METAL FILM: 900K ohms, 1%, 1/4 watt	18555-69
R244		RESISTOR, VARIABLE: 100 ohms, 30%, 1/2 watt	16925-910
R245		Same as R103	
R246		Same as R103	
R247		RESISTOR, FIXED, METAL FILM: 111K ohms, 1%, 1/8 watt	18554-128
R248		RESISTOR, FIXED, METAL FILM: 215 ohms, 1%, 1/4 watt	18555-180
R249		Same as R248	
R250	*	Same as R111	
R251	*	Same as R111	
R252		RESISTOR, VARIABLE: cermet, 100 ohms, .5 watt	16925-837
R253		RESISTOR, FIXED, DEPOSITED CARBON: 3.9K ohms, 5%, 1/4 watt	18470-392
R254		RESISTOR, FIXED, DEPOSITED CARBON: 36 ohms, 5%, 1/4 watt	18470-360
R255		Same as R254	
R256		RESISTOR, FIXED, DEPOSITED CARBON: 11K ohms, 5%, 1/4 watt	18470-113

* Models 517 and 5315 only

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R257		RESISTOR, FIXED, DEPOSITED CARBON: 910 ohms, 5%, 1/4 watt	18470-911
R258	*	Same as R219	
R259	*	Same as R140	
R260		RESISTOR, FIXED, DEPOSITED CARBON: 510 ohms, 5%, 1/4 watt	18470-511
R261		Same as R260	
R262	*	RESISTOR, FIXED, DEPOSITED CARBON: 3.3K ohms, 5%, 1/4 watt	18470-332
R263	*	Same as R219	
R264		RESISTOR, FIXED, DEPOSITED CARBON: 5.6 ohms, 5%, 1/4 watt	18555-126
R265		Same as R242	
R266		Same as R219	
R267		Same as R225	
R268	*	RESISTOR, FIXED, DEPOSITED CARBON: 180 ohms, 5%, 1/4 watt	18470-181
R269		RESISTOR, FIXED, DEPOSITED CARBON: 360 ohms, 5%, 1/4 watt	18470-361
R270		RESISTOR, VARIABLE: cermet, 10K ohms, 20%, 1/2 watt	16925-901
R271	*	Same as R203	
R272	*	Same as R140	
R273	*	Same as R201	
R274	*	Same as R133	
R275		Same as R133	
R276	*	Same as R268	
R277	*	Same as R202	
R278	*	Same as R211	
R279	*	Same as R210	
R280	*	Same as R203	
R281	*	Same as R103	
R282	*	Same as R133	
R283	*	Same as R218	
R284	*	Same as R108	
R285	*	Same as R103	
R286	*	Same as R223	
R287A, B	*	Same as R224A,B	
R288	*	Same as R268	
R289	*	Same as R228	
R290	*	Same as R230	
R291	*	Same as R231	
R292	*	Same as R225	
R293	*	RESISTOR, FIXED, DEPOSITED CARBON: 110 ohms, 5%, 1/4 watt	18470-111
R294	*	Same as R229	
R295	*	RESISTOR, VARIABLE: 2.5K ohms, p/o S205	
R296	*	Same as R219	
R297		Not used	
R298	*	Same as R218	
R299	*	Same as R293	
R300	*	RESISTOR, FIXED, DEPOSITED CARBON: 120 ohms, 5%, 1/4 watt	18470-121
R301	*	Same as R238	
R302	*	Same as R133	
R303	*	Same as R244	
R304	*	RESISTOR, VARIABLE: 2.2K ohms, 20%, .1 watt	16925-854
R305	*	Same as R103	
R306	*	RESISTOR, FIXED, DEPOSITED CARBON: 2K ohms, 5%, 1/4 watt	18470-202
R307	*	Same as R306	
R308	*	Same as R306	

*** Models 517 and 5315 only**

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R309	*	Same as R300	
R310	*	Same as R306	
R311	*	Same as R243	
R312	*	RESISTOR, FIXED, METAL FILM: 324 ohms, 1%, 1/4 watt	18555-197
R313	*	Same as R312	
R314	*	Same as R218	
R315	*	Same as R218	
R316	*	Same as R247	
R317	*	Same as R253	
R318	*	Same as R256	
R319	*	Same as R257	
R320	*	Same as R252	
R321		Same as R252	
R322	*	Same as R103	
R323	*	RESISTOR, FIXED, DEPOSITED CARBON: 1 megohm, 5%, 1/4 watt	18470-105
R324	*	Same as R323	
R325	*	Same as R323	
R326		Same as R133	
R327		Same as R201	
R328	*	Same as R201	
R329		Not used	
R330	***	RESISTOR, FIXED, DEPOSITED CARBON: 430 ohms, 5%, 1/4 watt	18470-431
R331	***	RESISTOR, FIXED, DEPOSITED CARBON: 620 ohms, 5%, 1/4 watt	18470-621
R332	***	RESISTOR, FIXED, DEPOSITED CARBON: 820 ohms, 5%, 1/4 watt	18470-821
R333	***	Same as R330	
R334	***	RESISTOR, FIXED, METAL FILM: 953 ohms, 1%, 1/4 watt	18555-184
R335	***	Same as R330	
R336	***	Same as R260	
R337	***	Same as R218	
R338	***	Same as R146	
R339		Not used	
R340	***	Same as R218	
R341	***	Same as R223	
R342	***	Same as R242	
R343	***	RESISTOR, VARIABLE: 4.7K, horizontal mounting	16925-895
R344		Not used	
R345	***	Same as R262	
R401		RESISTOR, FIXED, DEPOSITED CARBON: 150K ohms, 5%, 1/4 watt	18470-154
R402		RESISTOR, FIXED, DEPOSITED CARBON: 62K ohms, 5%, 1/4 watt	18470-623
R403		RESISTOR, FIXED, DEPOSITED CARBON: 240 ohms, 5%, 1/4 watt	18470-241
R404		Same as R153	
R405		RESISTOR, FIXED, DEPOSITED CARBON: 200 ohms, 5%, 1/4 watt	18470-201
R406		Same as R211	
R407		Same as R238	
R408		Same as R306	
R409		Same as R236	
R410		Same as R242	
R411		Same as R242	
R412		Same as R300	
R413		Same as R300	
R414		RESISTOR, FIXED, METAL OXIDE: 15K ohms, 5%, 4 watt	18575-761
R415		Same as R414	

* Models 517 and 5315 only

*** Model 5015 only

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R416		Same as R219	
R417		Same as R253	
R418		RESISTOR, VARIABLE: 5K ohms, 30%, 1/2 watt, p/o dual variable resistor 16925-909	
R419		RESISTOR, FIXED, DEPOSITED CARBON: 5IK ohms, 5%, 1/4 watt	18470-513
R420		RESISTOR, FIXED, DEPOSITED CARBON: 2.7K ohms, 5%, 1/4 watt	18470-272
R421		Same as R133	
R422		RESISTOR, FIXED, DEPOSITED CARBON: 4.3K ohms, 5%, 1/4 watt	18470-432
R423		RESISTOR, FIXED, DEPOSITED CARBON: 27K ohms, 5%, 1/4 watt	18470-273
R424		Same as R300	
R425		Same as R268	
R426		Same as R111	
R427		RESISTOR, VARIABLE: 10K ohms, 30%, 1/2 watt (horiz. position)	16925-905
R428		Same as R268	
R429		Same as R103	
R430		Same as R225	
R431		RESISTOR, VARIABLE: 10K ohms, 20%, 1 watt	16925-914
R432		Same as R269	
R433		Same as R133	
R434		Same as R269	
R435		Same as R153	
R436		Same as R225	
R437		Same as R225	
R438		Same as R238	
R439		Same as R225	
R440		Same as R238	
R441		Same as R211	
R442		Same as R203	
R443		Same as R111	
R444		RESISTOR, FIXED, DEPOSITED CARBON: 220 ohms, 5%, 1/4 watt	18470-221
R445		Same as R431	
R446		Same as R323	
R447		Same as R268	
R448		Same as R107	
R449		Same as R111	
R450		Same as R331	
R451		Same as R293	
R452		RESISTOR, FIXED, DEPOSITED CARBON: 36K ohms, 5%, 1/4 watt	18470-363
R453		Same as R102	
R454		RESISTOR, FIXED, DEPOSITED CARBON: 22 ohms, 5%, 1/4 watt	18470-220
R455		RESISTOR, FIXED, DEPOSITED CARBON: 1.1K ohms, 5%, 1/4 watt	18470-112
R456		Same as R153	
R457		Same as R431	
R458		Same as R431	
R459		Same as R108	
R460		RESISTOR, VARIABLE: time/cm, 25K ohms, p/o S404	
R461		Same as R137	
R462		RESISTOR, FIXED, DEPOSITED CARBON: 1.5 megohms, 5%, 1/4 watt	18470-155
R463		Same as R225	
R464		RESISTOR, FIXED, DEPOSITED CARBON: 750K ohms, 5%, 1/4 watt	18470-754
R465		RESISTOR, FIXED, DEPOSITED CARBON: 300K ohms, 5%, 1/4 watt	18470-304
R466		Same as R102	
R467		Same as R236	
R468		Same as R401	

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R469		RESISTOR, FIXED, DEPOSITED CARBON: 7.5K ohms, 5%, 1/4 watt	18470-752
R470		RESISTOR, FIXED, DEPOSITED CARBON: 75K ohms, 5%, 1/4 watt	18470-753
R471		RESISTOR, FIXED, DEPOSITED CARBON: 30K ohms, 5%, 1/4 watt	18470-303
R472		RESISTOR, FIXED, DEPOSITED CARBON: 910K ohms, 5%, 1/4 watt	18470-914
R473		Same as R104	
R474		Same as R469	
R475		Same as R472	
R476		RESISTOR, VARIABLE: 100K ohms, 30%, 1/2 watt, p/o dual variable resistor 16925-909	
R477		Same as R107	
R478		Same as R133	
R479		Same as R108	
R480		RESISTOR, FIXED, DEPOSITED CARBON: 91K ohms, 5%, 1/4 watt	18470-913
R481		Same as R402	
R482		Same as R306	
R483		Same as R108	
R484		Same as R306	
R485		Same as R107	
R486		Same as R107	
R487		Same as R213	
R488		Same as R213	
RT101		RESISTOR, THERMISTOR	18682-55
S101	*	Part of pushbutton switch 19910-265	
S101	**	SWITCH: pushbutton, 1 station	19910-267
S201		SWITCH: rocker, dp 3 position	19911-189
S202		SWITCH: rotary (vertical attenuator)	19912-724
S203		Same as S201	
S204	*	Same as S201	
S205	*	Same as S202	
S206	*	Part of pushbutton switch 19910-265	
S207	*	Part of pushbutton switch 19910-265	
S208	*	Part of pushbutton switch 19910-265	
S209	*	Part of pushbutton switch 19910-265	
S401		Part of pushbutton switch 19910-266	
S402		Part of pushbutton switch 19910-266	
S403		Part of pushbutton switch 19910-266	
S404		SWITCH: rotary (horiz. sweep)	19912-722
S405		Part of pushbutton switch 19910-266	
S406		Part of pushbutton switch 19910-266	
T101		TRANSFORMER: power output	20800-490
T102		TRANSFORMER: coupling	20800-403
V101		TUBE: CRT, 5DEP31F	20875-291
Z101		INTEGRATED CIRCUIT: MC14049CL, CMOS hex inverter	9800-196
Z102		INTEGRATED CIRCUIT: 7815, 15 volts, 3 terminal positive regulator	9800-192
Z103		INTEGRATED CIRCUIT: MC14001CL, CMOS quad 2-input NOR gate	9800-96
Z104		INTEGRATED CIRCUIT: MC7915	9800-197
Z105		INTEGRATED CIRCUIT: NE555V, timer	9800-113
Z106		INTEGRATED CIRCUIT: 78L05, 5 volts, 100 ma, voltage regulator	9800-171
Z107		INTEGRATED CIRCUIT: MC14013CL, CMOS dual D-type flip flop	9800-111
Z201	*	INTEGRATED CIRCUIT: quad analog gate 34066 PC or CD4066AE	9800-155
Z401		INTEGRATED CIRCUIT: TTL, DM/SN7400N	9800-65
Z402		Same as Z401	

*** Models 517 and 5315 only**

**** Models 515, 5015, and 5015LD only**

FIG 7-1 BOARD ASSEMBLY – POWER SUPPLY

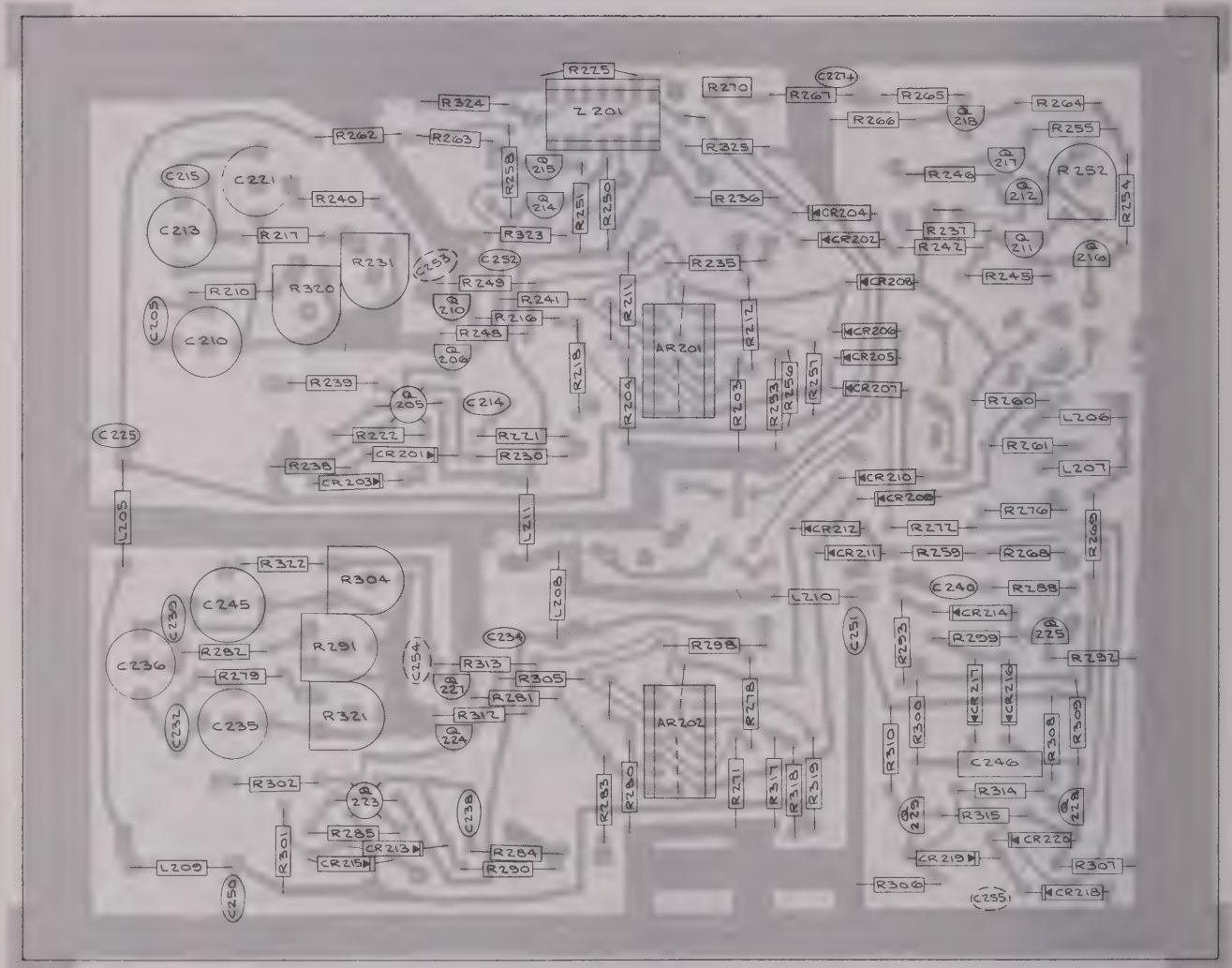
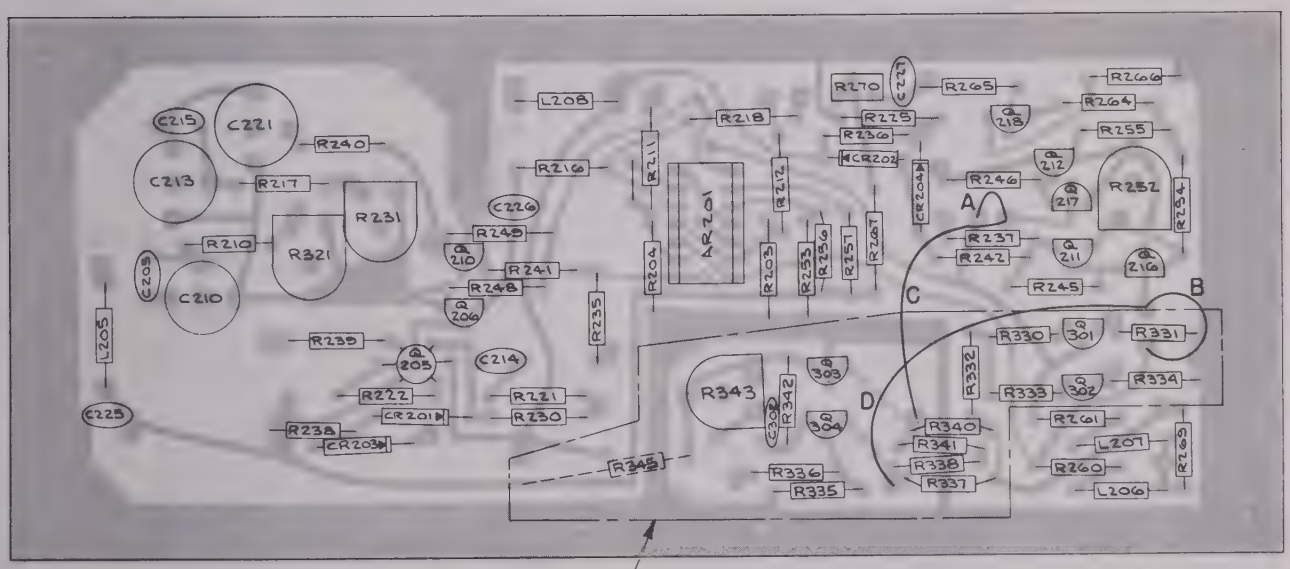


FIG 7-2 BOARD ASSEMBLY – VERTICAL
(DUAL CHANNEL ONLY)



COMPONENTS WITHIN PHANTOM LINE USED ON MODEL 5015 ONLY

JUMPERS 'A' + 'B', MODEL 515 ONLY
JUMPERS 'C' + 'D', MODEL 5015 ONLY.

FIG 7-3 BOARD ASSEMBLY – VERTICAL
(SINGLE CHANNEL ONLY)

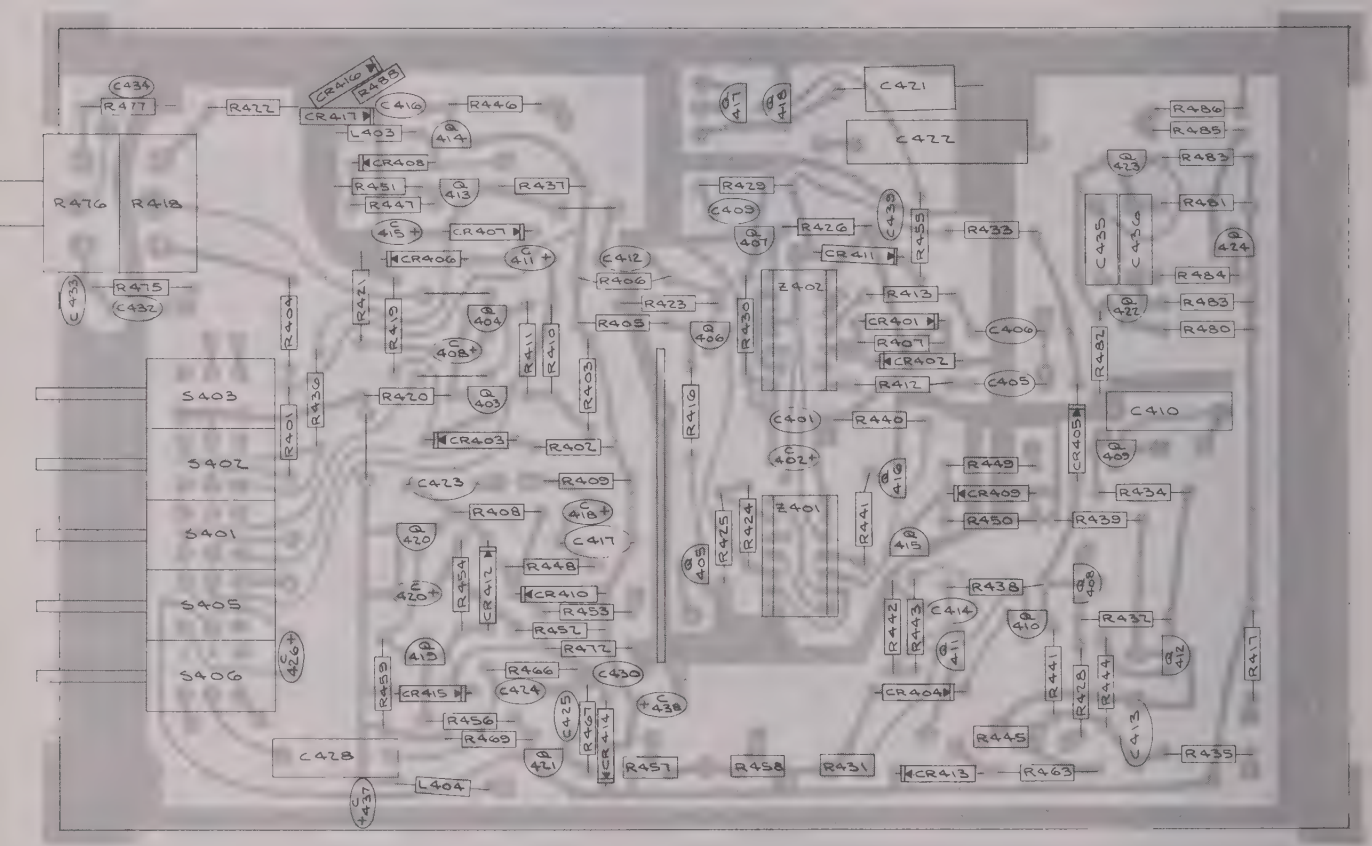


FIG 7-4 BOARD ASSEMBLY – SWEEP

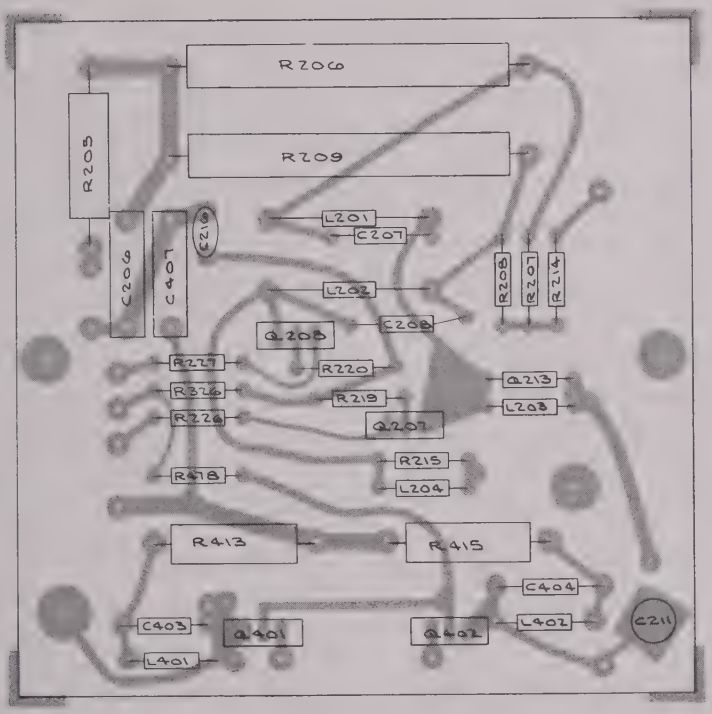


FIG 7-5 BOARD ASSEMBLY – FINAL

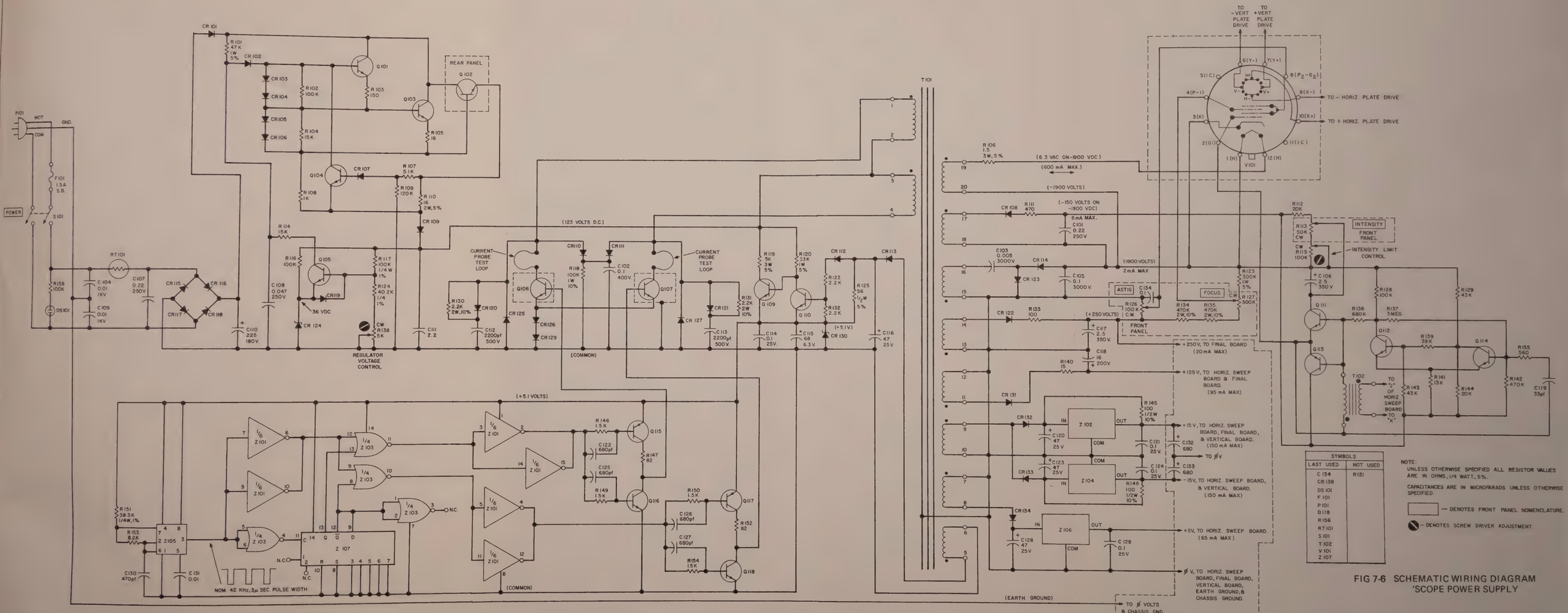
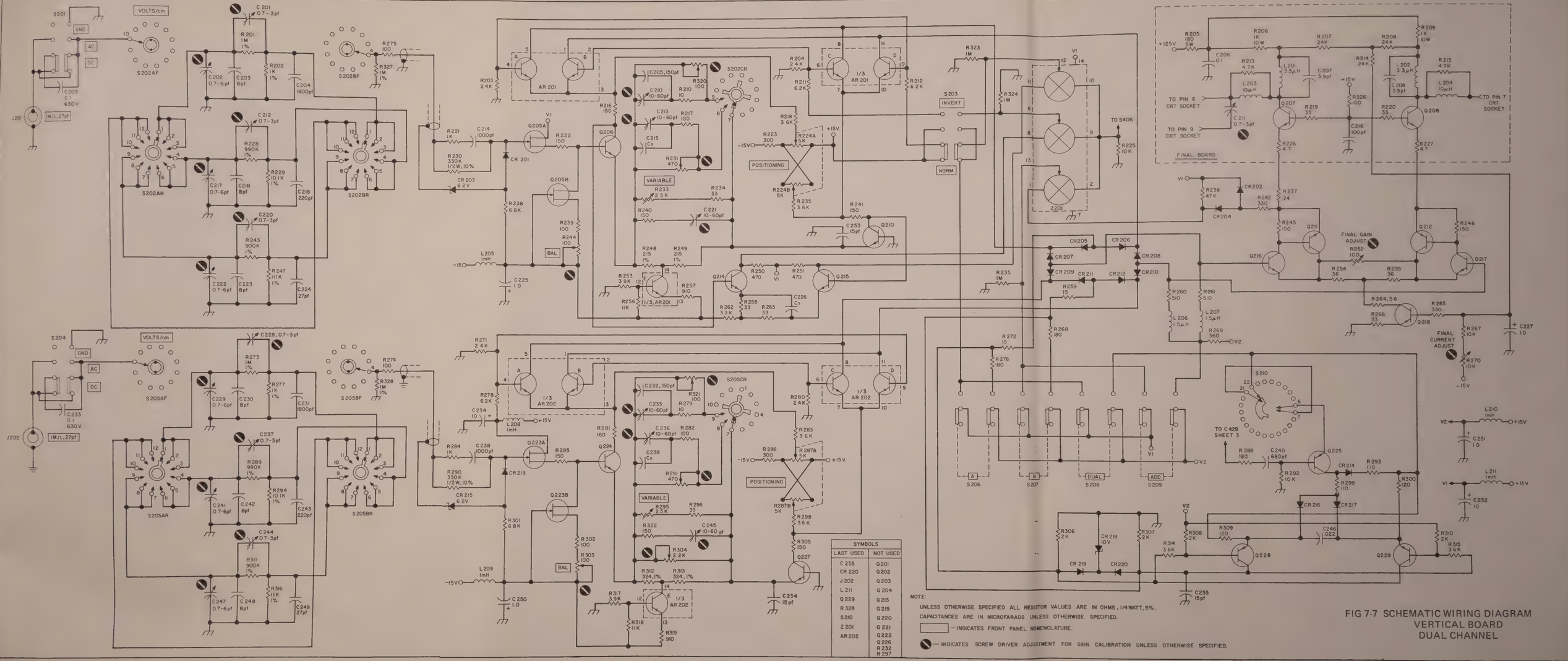


FIG 7-6 SCHEMATIC WIRING DIAGRAM 'SCOPE POWER SUPPLY



SYMBOLS	
LAST USED	NOT USED
C 255	Q 201
CR 220	Q 202
J 202	Q 203
L 211	Q 204
Q 229	Q 213
R 328	Q 219
S 210	Q 220
Z 201	Q 221
AR 202	Q 222
	Q 226
	R 232
	R 297

NOTE:

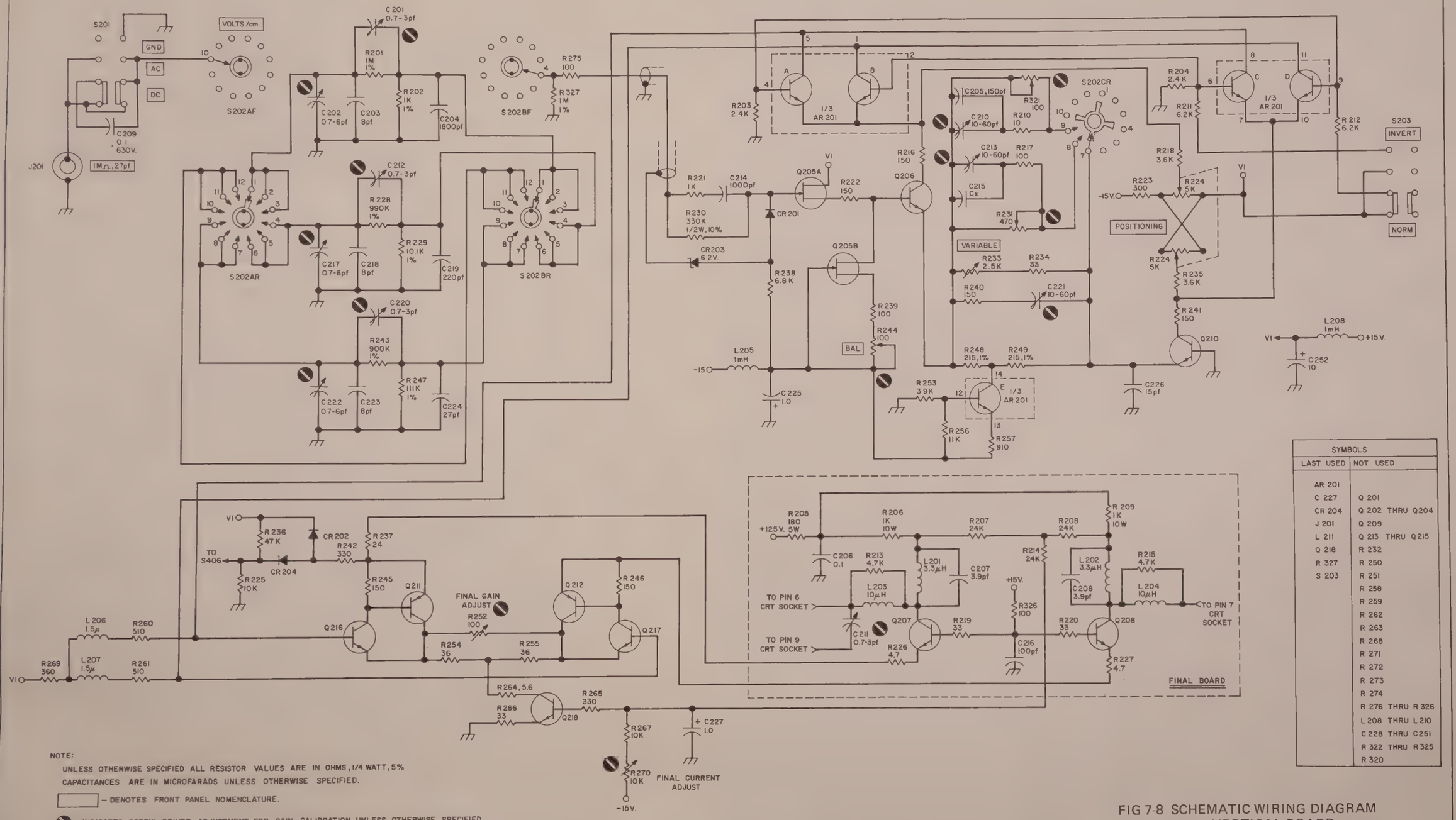
UNLESS OTHERWISE SPECIFIED ALL RESISTOR VALUES ARE IN OHMS, 1/4 WATT, 5%.

CAPACITANCES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

▭ — INDICATES FRONT PANEL NOMENCLATURE.

⊘ — INDICATES SCREW DRIVER ADJUSTMENT FOR GAIN CALIBRATION UNLESS OTHERWISE SPECIFIED.

FIG 7-7 SCHEMATIC WIRING DIAGRAM
VERTICAL BOARD
DUAL CHANNEL



SYMBOLS	
LAST USED	NOT USED
AR 201	
C 227	Q 201
CR 204	Q 202 THRU Q204
J 201	Q 209
L 211	Q 213 THRU Q215
Q 218	R 232
R 327	R 250
S 203	R 251
	R 258
	R 259
	R 262
	R 263
	R 268
	R 271
	R 272
	R 273
	R 274
	R 276 THRU R 326
	L 208 THRU L 210
	C 228 THRU C251
	R 322 THRU R 325
	R 320

NOTE:
UNLESS OTHERWISE SPECIFIED ALL RESISTOR VALUES ARE IN OHMS, 1/4 WATT, 5%
CAPACITANCES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

[ ] – DENOTES FRONT PANEL NOMENCLATURE.

⊘ – INDICATES SCREW DRIVER ADJUSTMENT FOR GAIN CALIBRATION UNLESS OTHERWISE SPECIFIED.

FIG 7-8 SCHEMATIC WIRING DIAGRAM
VERTICAL BOARD
SINGLE CHANNEL EXCEPT 5015

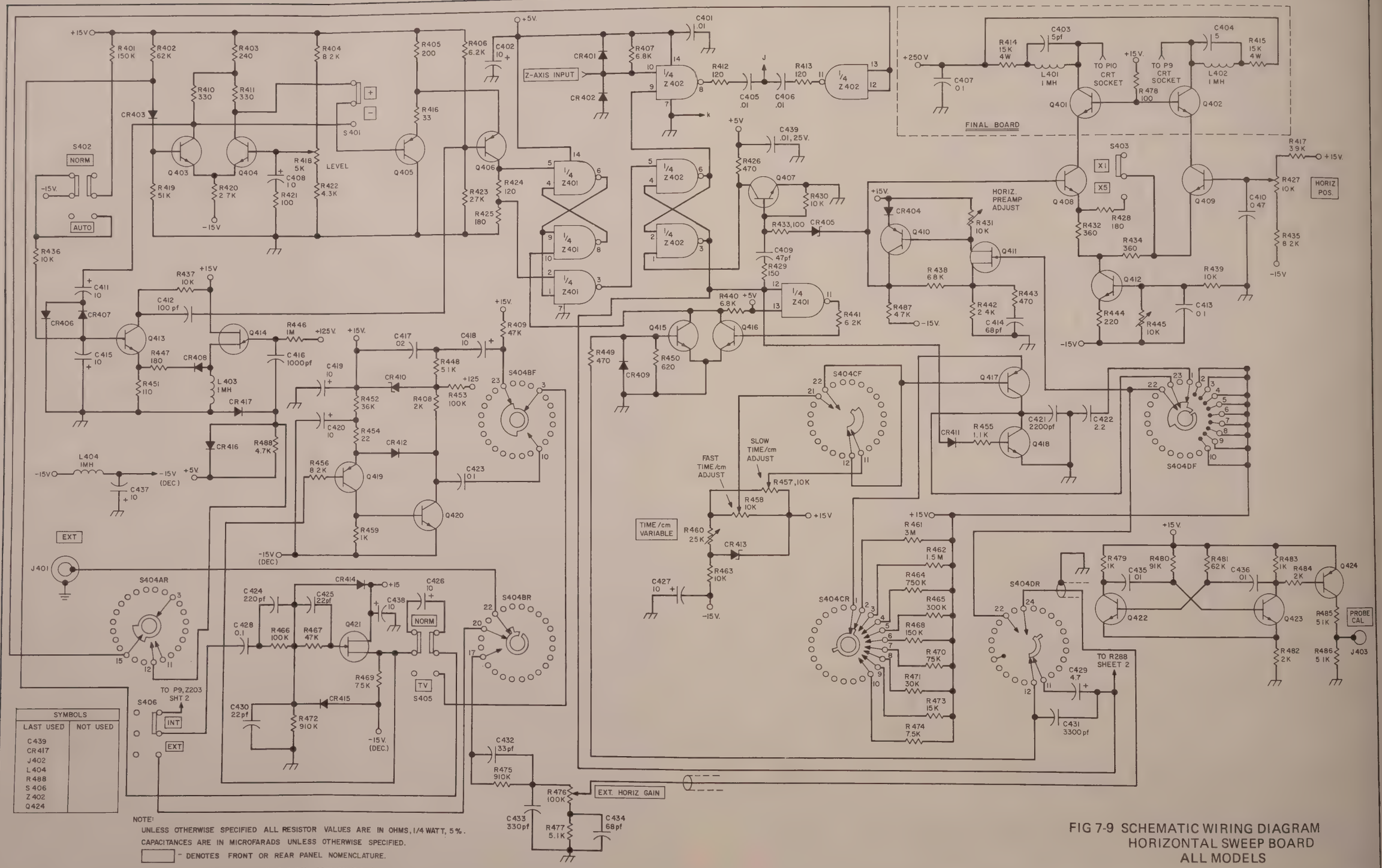
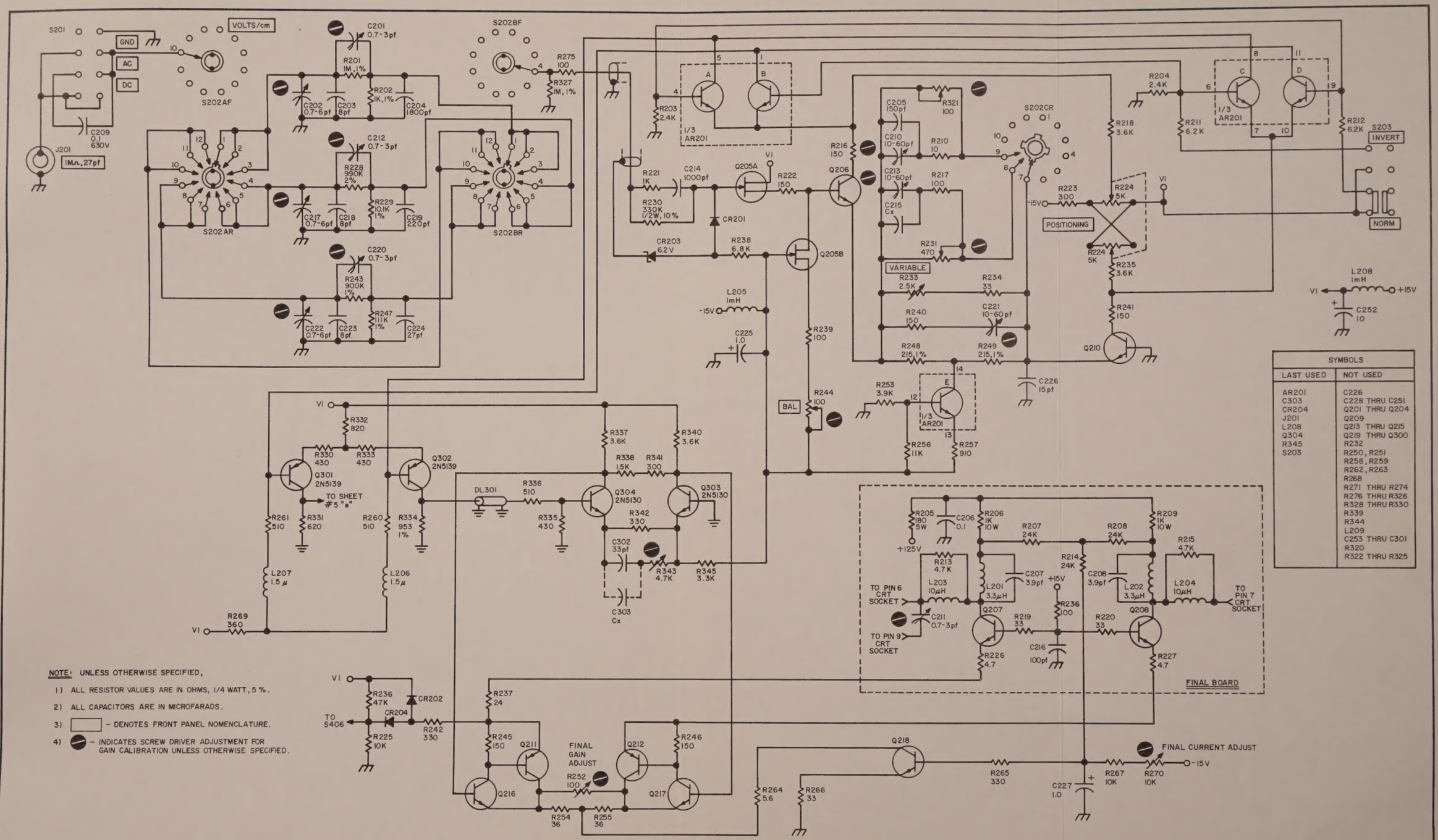


FIG 7-9 SCHEMATIC WIRING DIAGRAM
HORIZONTAL SWEEP BOARD
ALL MODELS



SYMBOLS	
LAST USED	NOT USED
AR201	C226
C303	C228 THRU C251
CR204	Q201 THRU Q204
J201	Q209
L208	Q213 THRU Q215
Q304	Q219 THRU Q300
R345	R232
S203	R250, R251
	R258, R259
	R262, R263
	R268
	R271 THRU R274
	R276 THRU R326
	R328 THRU R330
	R339
	R344
	L209
	C253 THRU C301
	R320
	R322 THRU R325

NOTE: UNLESS OTHERWISE SPECIFIED,

1) ALL RESISTOR VALUES ARE IN OHMS, 1/4 WATT, 5 %.
2) ALL CAPACITORS ARE IN MICROFARADS.
3) ☐ – DENOTES FRONT PANEL NOMENCLATURE.
4) ⊖ – INDICATES SCREW DRIVER ADJUSTMENT FOR GAIN CALIBRATION UNLESS OTHERWISE SPECIFIED.

FIG 7-10 SCHEMATIC WIRING DIAGRAM
VERTICAL BOARD
MODEL 5015 ONLY